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ASSOCIATION OF ENGINEERING SOCIETIES.

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No. 1.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

HEATING AND VENTILATING WORKSHOPS.

BY JOHN WALKER, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read September 13, 1887.]

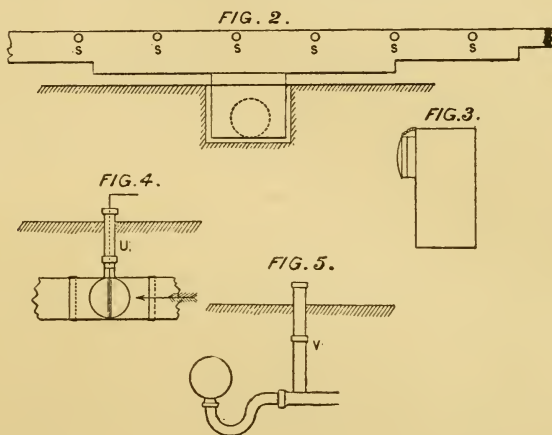
While extending our works* in the fall of 1886, the subject of heating our shops received considerable attention, mainly on account of the shops being somewhat scattered. We desired to establish some system that would be adapted to extensive shops, and at the same time be economical. After looking over the various methods of steam heating, and that of heating by hot air, we decided to try the latter. It occurred to us that hot air had been successfully used in drying almost all conceivable kind of articles, and especially lumber, so that its adoption to heat workshops by discharging hot air into same could scarcely prove unsuccessful. The peculiarity, however, of the location of our shops, their distance apart being considerable, presented difficulties for conducting the heated air from one shop to the other. In order that you may better understand same, I have provided a plan of our works (see Fig. 1).

The entire enclosure being about seven acres, and bounded on the East by Waverly avenue, on the South by Breakwater street, 520 feet to the lot line; on the West by the lot line, and on the North by the L. S. & M. S. Railway.

The railroad switches are represented by *A* and *B*; the original part of works is shown on the west side, *C* being warehouse, *D* being machine-shop two stories in height, *E* being blacksmith-shop, *F* being No. 1 foundry, *G* engine and boiler room No. 1; the northeast portion is the new part of works, *H* being the office, *I* machine-shop, *J* pattern vault, *K* foundry, *L* melting-house for foundry, *M* engine and boiler room No. 2; the distance from engine and boiler room *M* to receiver of hot air *N* at the original part of works is 355 feet; in boiler room No. 2 we placed a 6 × 9 Sturtevant Blower, perpendicular diameter of housing

* The Walker Manufacturing Co., located at Cleveland, Ohio, John Walker, Manager

piping we place 6-inch openings in its side, as shown at *S* (see Figs. 2 and 3), which have a loose cover much the same as a milk can cover, secured in place with chains, and can be placed over the openings or left off at will, so that any desired part of the shop may be warmed. In passing under doors or openings in the buildings, we invariably used sewer pipe under ground, and connected same to the galvanized piping after passing said doors; the line *P* passes under No. 2 engine foundation, through into the yard as shown, in the rear of office, where at points *T T* we take off two 10-inch branches at right angles, to heat the office, which is a building 40 feet square, two stories in height; we carry the sewer pipes into the building and then connect rectangular galvanized pipes immediately under the floor between the joists, and open same on the first floor with four 9 inch \times 12 inch ordinary registers, and then pass vertically against the wall with 12 inch \times 6 inch galvanized piping to the second floor,



with a similar pipe again under the floor and between the joists, which opens on the second floor with four 8 inch \times 12 inch ordinary registers.

At the point *U* in the 24-inch sewer pipe we placed a valve, as shown in Fig. 4, so that we could regulate the amount of hot air delivered to the original portion of our works, and retain as much as we needed for the new portion of works and office; this valve is operated from the surface outside, the stem of valve passing up through a 6-inch sewer pipe, which has a cover on its upper end for 1 inch rod to work in; after leaving the point *U* the 24-inch sewer-pipe passes under the railroad switch *A*, across the yard on an angle as shown, and underneath railroad switch *B* into receiver *N*, then through the shops, underground as before, to suitable points for outlets, which are provided with similar arrangements, as shown in Figs. 2 and 3.

The locations *V* being the lowest in the line of piping, we deemed it necessary to provide an arrangement for draining off the water should any find its way into the 24-inch main. Fig. 5 is an illustration showing the way this was accomplished; we coupled to the bottom of main an ordinary bend, as shown, so that the water accumulating in the main

would pass off through the 6-inch trap and pipe, as shown. We provided a vertical pipe coming above ground with a cover on same, so that we could look down into the 6-inch drain at any time and see if any water was passing; the exposure of a 6-inch surface of water in the main proved to be of no serious objection; in rainy or thawing weather the 6-inch drain would show a small amount of water passing continually, but in frosty weather same would cease.

From the description given, you will notice that the entire line of mains are underground, which was quite a questionable undertaking, as the amount of absorption of heat by the earth was likely to interfere with its successful working. After being completed, and having started the blower, we found this to be the case for several days, but after running the blower four days and nights we then got heated air at the receiver *N*, which showed that the earth surrounding the pipe had been absorbing the heat; on the fifth day, after running the blower continually, we found that the snow melted on the ground, locating the line of pipes throughout the yard. After this we continued to run without any perceptible loss from radiation; the ground had, no doubt, been dried out for a diameter equal to eight feet. We continued the use of the plant for the entire winter with excellent success, but we found that at the receiver *N* and at the various openings in the original shops, that we had not sufficient heat for the coldest of weather, and at once put in a series of pipes about 20 feet in advance of the receiver *N*, so as to reheat the air on its passage to shops; same was supplied with steam from boiler No. 1, and proved entirely satisfactory. In operating the manifold pipes in vaults it is necessary to let the steam enter so that it will pass to the greatest number of pipes, always allowing the water from condensation to pass by gravitation to a trap. In this arrangement we provided a tank some four feet in diameter and nine feet deep underground in boiler-house No. 2 to receive the condensed water from the pipes through trap. By this means we were enabled to use full boiler pressure on the manifold pipes, which gave us the greatest amount of heat, and could change to exhaust steam in moderate weather. In the same tank we placed a float valve from the city water-works, and mixed the water at will. The water was returned to the boiler at about 180 degrees temperature, thus saving considerable water and heat with same by using the water over again instead of blowing same through the steam pipes, as is usual in steam heating in buildings.

It will be seen that no steam pipes leave the boiler-room, hence they are all protected against frost and leakage, the water being trapped out as fast as it accumulates.

The advantages of this system are :

First : It is economical in use.

Second : It is economical in repairs.

Third : There is no danger of bursting pipes and flooding the shops with water.

Fourth : Cleanliness ; the engineer firing his boiler as usual, and wheeling out his ashes, and to all appearance there is nothing more going on than would ordinarily be expected about an engine and boiler room.

Fifth : The displacement and circulation of air in the work-shops by

forcing the warm air in. This is particularly advantageous in our foundries, where the introduction of heated air carries away the smoke incident to the various operations of a foundry. It will also be seen that when the heated air is introduced the cold air must be displaced, passing out at whatever place it can.

Sixth: The galvanized pipes of themselves are warm with the heated air, and serve as an excellent means for keeping cores dry for molder's use; and whenever a molder wishes to dry off his patterns he can do so without injury, let them be ever so delicate, by placing them near the galvanized pipes.

Seventh: In summer time the entire system is applicable to cooling and ventilating the works without the slightest change, same as the man who cooled his dinner and warmed his hands with the same breath, nothing further being required than having a tight stop-valve, so that no steam can pass through into the manifold pipes.

It would be safe to say that the temperature in our office during the hot days of the past summer was lowered from five to ten degrees, and the circulation of air was perfect by this means.

So far as we are aware, this is the first time that hot air has been attempted to be carried a long distance underground, and we consider the success of this case quite an important demonstration, where similar systems may be needed or useful.

METHODS USED IN FILLING A PORTION OF SOUTH BOSTON FLATS BY THE COMMONWEALTH OF MASSACHUSETTS.

BY FRANK W. HODGDON, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read September 21, 1887.]

The South Boston Flats, so called, is a tract of about 700 acres lying between South Boston, Fort Point Channel, the Main Ship Channel and Castle Island. About 90 acres were given by the State to the Boston Wharf Company and have been filled by it.

About 65 acres have been sold unfilled to the N. Y. & N. E. R. R. Co. and have been nearly filled by it. About 120 acres of the remainder have been filled by the State. The surface of the flats averaged about 2 feet below mean low water.

The material for filling to the height of 13 feet above mean low water has nearly all been dredged from various parts of the harbor, mainly from the area adjoining and northerly of the filled area. The material is principally clay, in some places mixed with more or less fine sand; at other places is found a fine, firm black sand, and in others a fine gravel; but the principal part is clay, blue and yellow.

The contractor's plant consisted of dredging machines, tow boats, hopper-bottom scows, railroad track on pile trestle, and locomotives and cars.

In the first place, after the area to be filled has been protected on its harbor side by sea walls or bulkheads, the material is dredged and placed in the scows, which are floated at high water on to the area to be filled

and dumped there, and this is continued as long as the scows can be floated in, and the filling can be done in this way up to an average of about 3 feet above mean low water.

When this is completed, the loaded scows are floated alongside a wharf or pier, which is built just outside the area to be filled, and dumped there. Then the material is redredged by a clam shell dredge and placed in cars, which are run down on the wharf. The loaded cars are hauled out on the pile trestles, which are built across the area being filled, and dumped there, and upon the method of dumping depends very much of the success of the work.

The cars dump from both sides, one-half the load going on each side, as will be seen by the sketch of a section of car and trestle (Fig. 1).

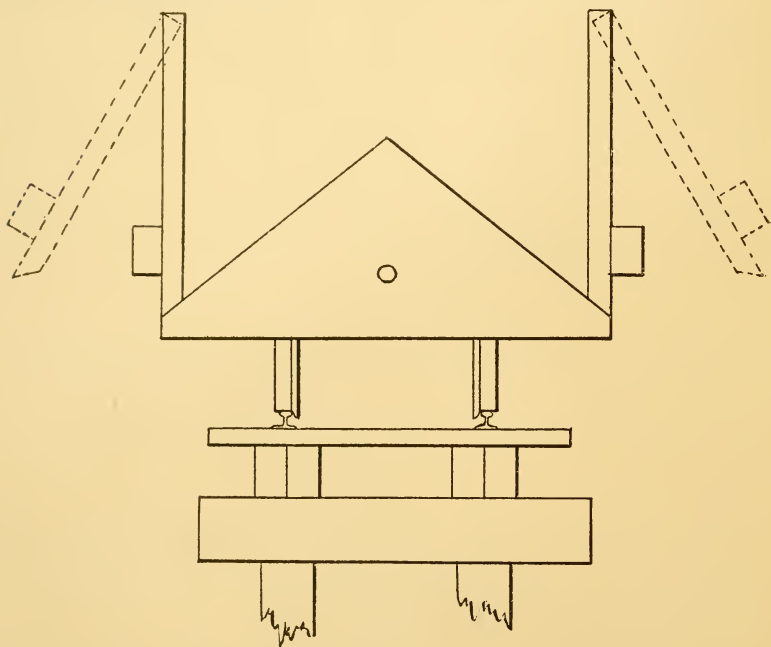


Fig. 1.

The cars on 3 feet gauge, with which most of the work was done, carry about 7 cubic yards, and on 4 feet 8½ inch gauge carry about 10 cubic yards.

In the first place a few cars are dumped along the whole length of the track to form a ridge around the piles and stiffen the track. Then the cars are dumped continuously in one place, usually the end of the track farthest from the pier. The material by the time it gets into the cars is in a semi-fluid state, and when it is dumped flows away from the track, and when it is unobstructed assumes a slope of from 20 to 1 to 25 to 1. Great care has to be taken to keep the dump moving after it has got to be pretty large, because if it gets set and dry on the surface by not working for a few days all that is dumped afterwards will be on top and not settle into the centre to force the rest out.

The dumping is continued until enough has been dumped to level off the area, or until the material covers the track and stops the cars. If enough cannot be dumped the first time, more has to be dumped after the first lot has been leveled off.

When one dump is finished another is started at about the edge of the slope of the first, and the same process gone through with. This is continued until the whole track has been used, and then a new track is started.

After the dumps are sufficiently dried out, a gang of laborers with shovels and wheelbarrows is set to work leveling them down to the required grade.

Sometimes while dumping the pressure of the dump is greater on one side of the track than on the other, and forces the track over to one side. Then the cars are loaded on one side only, by covering the other side with plank, and are run out and dumped on the weak side of the track and so force the track back into place.

At other times the material will not flow out from the track, and then shutes like toboggan slides are dug in the sides of the dump, and the cars dump the material through these with varying success.

The arrangement of tracks is shown on the accompanying plan (Fig. 2), page 8. The elevations vary from 2 feet to 8 feet above the finished grade.

The grade of the piers or elevating stations is made about extreme high water, if it can be done without making the grade up to the dumping trestles too steep, but the last station built was put at about 6 feet above mean high water.

The best results have been obtained by running the cars night and day on a high trestle, the material being clay.

The high trestles give the best results; that is, the largest amount of material deposited from a single track, but the height must be limited by the proportion of the dump which must be leveled by hand.

In filling a number of parallel tracks the second should be filled first, then the first, the fourth, the third, and so on, because if they were filled in order the filling of No. 2 would run against No. 1 and force No. 2 track over towards No. 3, and so on. About 150 feet on each side of a track is about the limit of economical work, as the leveling has to be done by wheelbarrows, as the mud is too soft to use horses and carts. The material dredged by scoops or dipper dredges in the first place and then loaded into the cars by clam shell dredges works very much better than that dredged in the first place by clam shell dredges and loaded into cars by a clam shell, as it is broken up more and the water mixes with it better. One contractor put his cars on scows and loaded them by a clam shell dredge directly from the original bank and then run them out over a transfer bridge on to the trestles and dumped them; but he found that very often the clay would not run out of the cars and had to be dug out by hand, and when dumped would not flow far from the trestle, it was so dry and in such large chunks.

The same contractor tried to run his cars on a track laid on the filling at the edge of the bank, and dump them in the same way as gravel filling is done, but the filling would not hold up the track, although he had his ties twelve inches wide and only two or three inches apart. He also

Traverse line of elevation

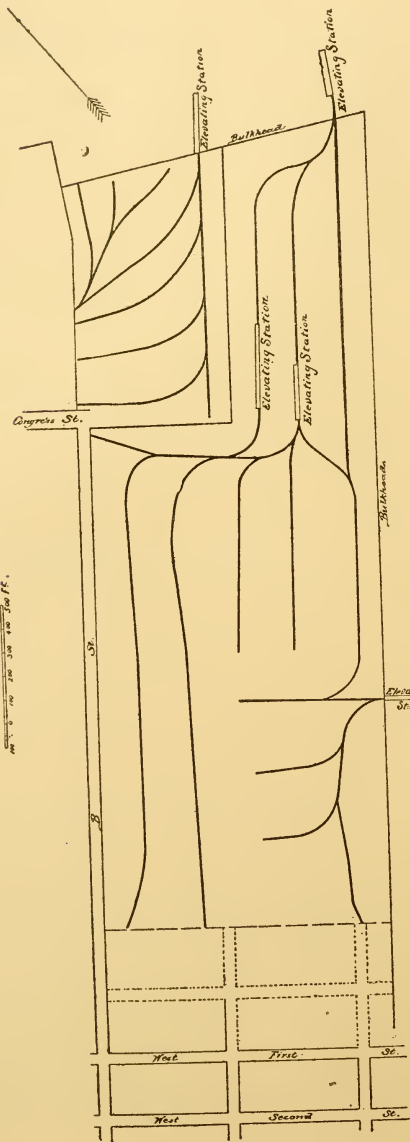


Fig 2.

tried to do his leveling with a scoop, worked first by oxen and then by a winding engine standing on one of the trestles, but he gave up all his experiments and finished his contract with wheelbarrows.

The timber bulkheads, which were built to inclose the area to be filled, was built as a temporary structure, and inside the lines of the proposed pier lines, and the clay filling was allowed to come directly against them. On the outside we dumped clay to the height of about half tide to strengthen them. For a distance of about 900 feet we allowed the mud to flow against it from a track about 100 feet away, and it stood nearly in place till the top of the bank against it was above high water mark, when the heads of the spur shores began to cripple and allow it to bulge.

The rest of the distance the mud was placed behind the bulkhead in layers by a clam shell dredge lying on the outside of the bulkhead and digging the mud in front of it and not nearer than 15 feet of the bulkhead, and this portion retains its place except for a short distance which had not been built long enough to allow the piles to get fully set in the clay, and they were pulled up by the spur shores, but the strong capping has held it all together. The work is paid for by the cubic yard, measured after being deposited and leveled, at the rate of 36, 46, and 50 cents per cubic yard in different localities.

Separate contracts for loading the material into cars and grading it after it has been deposited at the elevating stations are paid at the rate of 25 cents per cubic yard.

THE MUNICIPAL ENGINEER AND THE MANAGEMENT OF HIS OFFICE.

BY B. SCHREINER, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read September 6, 1887.]

As civil engineers who have spent their past at railroad work, or some special branch of civil engineering other than city engineering, often find opportunity to enter the municipal service, which will prove a new field to them, I should think that the varied knowledge of such of their colleagues, who have had experience for years in this special branch of engineering, would be of some service to them. This is the motive for this paper. Another object in view is to induce municipal engineers to communicate *their* experience to the profession.

The municipal engineer—"city engineer, city surveyor"—is either appointed by the city council, or he is elected by the citizens. In some instances the appointment rests with the mayor of the city, which appointment is usually subject to the approval of the council, but in most cases the duration of the appointment is limited to too short a space of time to give the engineer the necessary opportunity to so organize and conduct the technical service of the city government as to give the most efficient results. But, be this as it may, invariable is his position, partly that of a counsellor to the city council—consulting engineer—and partly as the chief of the technical branch of the city government—residen

engineer. This dual capacity makes it his duty to advise the council and its individual members as to necessary work, contracts, prospective improvements, etc., and upon municipal legislation in regard to such. And it is his further duty to organize and conduct the service of his office so as to facilitate systematical and efficient work in the field and in office; to make, respectively to revise, all plans, calculations, estimates and specifications, and to arrange and direct all the platting and map work. He must supervise all the field and office work done by and under his direction.

The engineer should never forget that he *is not* a clerk of the corporation government, but *its advisor*; that his office is executive as well as initiative, and that his position charges him with greater responsibilities and demands higher abilities than are required of any other officer of the municipal household. While the city attorney, by means of his legal learning, sparkling rhetoric, and shrewdness in managing juries may defeat litigations against the city, the engineer's judgment, based on knowledge and experience, will prevent them; by far the cheaper and wiser *modus operandi*; and he can do more toward a real growth, proper development and neat appearance of a city than any combination of real estate speculators, city boomers and party pushers will ever be able to accomplish.

As efficient work can only be expected or made possible through an intelligent arrangement of the entire office and field work and the *records thereof*, it is plain that manifold records are required. In the first place, the engineer must be fully posted as to the laws, ordinances and resolutions having any bearing to the work of his office. Therefore he should keep a record of them, stating at the head of each law, ordinance, etc., the book and page of original record, and giving date of its passage; and a correct and accurate index must be appended. An office day book is another necessary record upon which all ordinances, resolutions ordering work done, are entered, giving a short synopsis of what is required; and after the request is complied with, there should be made an entry on opposite page stating all necessary particulars. The engineer should keep a diary in which he should enter every day's doings, peculiar observations, meteorological notations, etc. That all communications and correspondence should be copied in the copy book is hardly necessary to say. Arriving correspondence, etc., should be filed, and the date answers are made—if such were required—should be marked on them, and a correct index be kept. These are about all the absolutely necessary records for transacting the usual routine business. For special work particular records will be required, such as assessment record—for entering each individual assessment against property for improvements, with such general notes as are deemed necessary—estimate book, material register, cement tests register, etc.

It is essential to have a "map" of the municipal territory, showing the government survey, with monuments and references to such, with the subsequent divisions and subdivisions into acre tracts and roads according to the deeds, with short memoranda as to book and page of deed record or road records, monuments, witnesses to such, distances and bearing of boundary lines, etc., and every difference in measurements found—

either surplus or shortage—fully marked. In connection with this map, goverment monuments should be preserved, respectfully made permanent, eventually be replaced and be brought in measurable relations with easily discernable, permanent, objects, and all the old evidences obtainable, as records, statements of witnesses, should be gathered and kept with the *map*. A scale of 500 feet to 1 inch will prove most convenient. If the territory is of such an extent as to make such *map* too large in one sheet, divide up into two or more sections. Another map which is necessary, is a plan of all the additions and subdivisions with the undivided property—corporation land—showing blocks, lots, streets, public squares, parks and alleys, with numbers and sizes, the names or designation of additions, etc., streets and public places plainly inscribed. The different additions and subdivisions can be made more plainly visible by bordering same with brush lines of different colors, while public land, railroad land, etc., can be made easily discernable by coloring with a definite shade of water color. A scale of 400 or 500 feet to 1 inch will prove most satisfactory. A copy of the foregoing described plat or map, with the horizontal contour lines accurately entered, will give a reliable topographical map, very necessary and useful in considering surface and underground drainage.

In connection with these maps there should be detail plats, say on a scale of 200 feet to 1 inch, made either in quarter sections (which I found the most convenient) or in consecutive sections of streets, giving additions, blocks and lots, with names, numbers and dimensions of same, as also the names of streets, public grounds, etc. These plats are very useful for tax assessors, as well as for special assessments, street improvements, sewers, etc., and the graphical record of public improvements and works.

For the convenience of establishing street grades, of questions as to grading of streets, calculation of approximate qualities, etc., the profile of every street should be entered on the profile book of ruled profile paper. Scales should be selected large enough to allow setting in figures for elevations, quantities, etc., and for references to the respective level books.

To simplify the work, and still to keep a thoroughly reliable and efficient record of work and results, the level books and different kinds of note books (field books) should be classified by capital letters (A, B, etc.), and each kind should consecutively be numbered each year, commencing with No. 1; and each book should be paged and fully and accurately indexed, so that in entering surveys on plats it will only be necessary to refer to the original record (as per ex., B., 15, 1886). And each entry in a level book or in any kind of note book should be headed with the date, with a short description of the work as to location and nature, and such observations as may seem to be, or to become of some service.

As to arrangements of plans, etc., office furniture, etc., I will only refer to the *Engineering News* of 1886 and 1887—municipal engineering—which will give all the information that may be desired.

In conclusion I will add that, although these suggestions are mainly calculated to state the necessities of an engineer's office of smaller com-

pass—where no Board of Public Works is supporting the engineer—I hope that some of the suggestions in this paper will be of interest to engineers of larger cities, and to members of boards of public works.

ON THE ACTION OF BOSTON WATER ON CERTAIN SORTS OF SERVICE PIPE.

BY THE LATE WM. RIPLEY NICHOLS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, AND L. K. RUSSELL.

[Read October 19, 1887, by Prof. L. M. Norton.]

Although galvanized pipe is used to a considerable extent for distributing soft water, and although the general nature of the action of water upon zinc is known, there are very few results of quantitative analysis accessible which show the amount of zinc actually taken up by the water under the circumstances of ordinary practice. We have recently made some experiments in this direction.

The principle on which the so-called “galvanizing” process rests is that, under ordinary circumstances, zinc is slightly electro-positive to iron, and if the two metals in intimate contact are simultaneously immersed in water the zinc will be acted upon rather than the iron. This principle is only partially realized in practice. As long as the zinc coating is perfect the iron is protected, but if the zinc coating be imperfect, or if it be removed, as it is liable to be in coupling pipes together, then the iron is acted upon as well and compounds of zinc as well as of iron are formed and carried forward with the water, or form a sediment which gradually chokes up the pipe. One of us has already stated elsewhere, as the result of experience, that it will usually be found possible to detect zinc in water which has passed through any considerable length of zinc pipe, and has expressed the opinion that with most waters which are used for water supply the amount of zinc in suspension—generally a hydrocarbonate—and in solution (in whatever form) is too inconsiderable to form the basis of a sanitary objection to the use of the pipe.

In our recent experiments we employed a length of about thirty-nine feet of half-inch galvanized pipe connected with the water service of the building in such a way that the water in the pipe could at any time be displaced by fresh water without allowing air to enter. Usually for a test an amount of water was drawn off equal to or slightly greater than the capacity of the pipe.

The experiments were continued during a period of three months. We found zinc in solution and in suspension, in not widely varying amounts, whenever water stood in the pipes from seven to seventy hours.

Water standing several days in the pipe contained no greater proportion of zinc in solution, though that in suspension was increased, and at the end of the three months the quantity of zinc found was only slightly less than at the beginning.

The water contained in solution 0.3 to 0.6 parts per 100,000 zinc. In

suspension 1.5 to 2 parts per 100,000, or 0.3 grain per gallon in solution, and 1.0 grain per gallon in suspension. No zinc was found in water with the regular flow, but when the rate was decreased to about one quart per hour, 0.9 parts per 100,000 of zinc in solution *and* suspension was found.

The inevitable inference to be drawn from these results is that the zinc coating is slowly but continuously dissolved, and it becomes a question of interest to consider the length of time the coating will last. Some experiments on the thickness of the zinc coating and the depth to which it penetrates the iron were made.

Some rods of wrought iron about six inches long were carefully centered and turned off by a lathe for about four inches of their length. The diameters of these were measured with a micrometre screw caliper measuring to one one-thousandth of an inch. The rods were now treated exactly as iron pipe is galvanized, *i. e.*, by dipping the iron previously cleaned by immersion in muriatic acid, into a bath of melted zinc, with frequent additions of sal-ammoniac, the centring being preserved by filling the holes with putty, which was afterwards easily dug out. The increase in thickness was noted. The rods were turned down by this amount, the turnings collected and analyzed for zinc and iron. Other turnings followed of varying thickness which were also analyzed.

The results are given in the following table. The measurements are the thickness of the consecutive layers removed :

No. of rod.	No. of consecutive turning.	Meas. before galvanizing. In. dia.	Meas. after galvanizing. In. dia.	Thickness of turning.	Per cent. Fe.	Per cent. Zn.
I.	1	.901	.905	.002	2.19	97.08
I.	2	.901	....	.0035	93.31	4.33
I.	3	.901	....	.002	96.04	.98
II.	1	.901	.905	.002	1.87	96.42
II.	2	.901	....	.003	65.24	33.18
II.	3	.901	....	.0025	....	tr.
III.	1	.901	.905	.002	1.70	97.20
III.	2	.901	....	.0025	62.03	33.95
III.	3	.901	....	.001	87.09	13.23

This table shows the increase in thickness due to galvanizing to be a ring of two one-thousandths of an inch thick and that zinc does penetrate slightly into the iron, forming an alloy.

It will be seen that at the rate of wear indicated in the first series of experiments the coating of zinc would not last many months.

The zinc coating is not an even layer over the whole surface, but is thinner in places. This was made evident by experiment as follows : On immersing one of the galvanized rods or a piece of pipe in water, points of iron rust appeared at irregular intervals. In the water drawn from the pipe as above described some iron was always found with the zinc.

Some experiments were also made to ascertain the composition of the insoluble precipitate formed by the action of water on zinc. A quantity of chemically pure zinc was placed in a large flask and covered with filtered Cochituate water. The precipitate formed was collected from

time to time, and the water was renewed, and was dried over sulphuric acid, one portion contained

ZnO	73.08
H ₂ O	16.90
CO ₂	10.02
	<hr/>
	99.92

Another portion dried longer gave

ZnO	78.44
H ₂ O	10.98
CO ₂	10.58
	<hr/>
	100.00

This composition nearly corresponds to $5\text{H}_2\text{O}, 2\text{CO}_2, 8\text{ZnO}$. This zinc hydrocarbonate differs somewhat from those investigated by Rose and v. Pettenkoffer.*

At the same time as the foregoing experiments, tests were made of a pipe protected by a coating of lead, tin and antimony (in the proportion of about 80-12-8 in the sample examined) instead of zinc. The pipe is called kalamein.

Our experiments show that the coating on our sample is not evenly laid on, the spots of iron showing as referred to in the case of the galvanized pipe. Our experiments extended over nearly a month, and the amount of lead and tin in the water drawn from the pipe was not appreciably diminished at the end of the time.

We also arranged brass pipe in the manner described for the galvanized, except that the two ends were connected so as to enable us to heat the lower part and keep up a circulation of water through the pipe, and to ascertain what metals if any went into solution. Zinc and copper were found in small quantities but constantly present.

As a further evidence of chemical action the dissolved oxygen in samples of water which had remained in contact with the pipes for fifteen hours was determined by Schutzenberger's method, fully aerated Cochituate being taken as a standard and the tests being made for several days in succession.

Freshly drawn and fully aerated Cochituate gave per thousand of

Kind of pipe.	Dissolved Oxygen.
Common iron pipe, from faucet in the laboratory, after 15 hours contact....	2.1
Brass pipe.....	1.6
Galvanized pipe.....	0.7
Kalameined pipe.....	0.6

STEAM HEATING.

BY CHARLES E. JONES, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read November 2, 1887.]

Previous to 1879 the buildings of Washington University were heated by the old style of cast-iron furnace, but during the summer of that year the University erected a boiler house and put in a steam plant to supersede the old and unsatisfactory furnaces.

* NOTE. —Rose, Pogg. Ann. 85, 107-141. A's v. Pettenkoffer, Abh. D. Tech. Commission, I., 149.

On October 20 of that year, now eight years ago, the writer hereof took charge of this steam apparatus. The boilers, three in number, have been described to this Club before, in a paper by Mr. Charles F. White in May, 1880. But as some of you may not have been present on that occasion, I will state that they are 16 feet long, 5 feet in diameter, containing 36 4-inch tubes, and have each 750 square feet of heating surface, and are rated 75 horse-power. The tubes are arranged so as to leave a space of 12 inches width in the centre, so that a man entering the man-hole on the lower side of the front head, can pass up between them, thus affording excellent opportunity for cleaning and inspection. This arrangement of the tubes to the best of my knowledge was an original idea of the late Prof. Chas. A. Smith, and it has proved a most excellent one, as it is this central water space, in my opinion, that has protected the boilers from injury during these eight years of the extremely heavy duty to which they have been subjected, and to the free and rapid circulation this space has afforded is probably due the remarkable work they have been found capable of. Two of these boilers, when designed, were expected to be amply large for the work of heating the buildings and running the engine in the manual training school shops, leaving one in reserve, for cleaning or repairs if necessary, but buildings since added and rooms in the old building not then occupied and not thought worth using, as they were difficult of access, but since brought into use to meet the growing demand for more room, necessitating the putting in of additional radiators, these have long since used up our reserve and compelled us to crowd all three of the boilers to double their rated capacity. It was also found upon careful measurement that the buildings are nearly 30 per cent. larger than they were considered to be in the original estimate. The buildings since added are the school building, at the manual training school (the shops now occupying all of the original building), the gymnasium and the observatory. These additions required an increase of about 21 per cent. in the heating pipes. An additional reason is also found in the higher temperature demanded by the occupants of many of the rooms. Formerly they were satisfied if the temperature reached 68 or 69 degrees F., now they demand 73 to 75 degrees F., and we have had complaints that this was not warm enough. This has always occurred in rooms heated indirectly, and, I think, must be owing to the fact that the occupants are in a gentle current of dry air; for we all know how much cooler it seems in summer on a day when the air is dry, than when it is charged with moisture, although the thermometer may read higher in the former case.

As we have both systems of heating at the University, direct and indirect, a brief consideration of the merits of the two systems may not be out of place here.

Experience has shown the indirect to be the most satisfactory where there are a number of persons congregated, and who remain in the room for a considerable time, which is owing to the perfect ventilation obtained by this means; and it is the unanimous testimony of the teachers engaged in rooms heated in this manner that when the rooms were heated by the old furnaces a short time in them would frequently bring on headache. Now they can spend an unlimited time in the rooms with

fect comfort. Pure air is not always found where the direct system prevails. As an instance of this, I well remember being called at one time to attend to a trifling leak around a valve stem in a room heated directly. There were about 60 boys in the room. On first entering from the pure, fresh air of outdoors I was surprised to find a disagreeable odor, which was also noticed by the janitor, who accompanied me. On inquiry I found that it was not perceptible to those who were in the room, they having been there some hours. The indirect system, however, is the most expensive in fuel, probably to the extent of 25 to 30 per cent., but the perfect purity of the atmosphere of the rooms justifies the additional expense. Another strong point in its favor lies in the fact of its being situated in the basement, which admits of any trifling derangement being attended to without disturbing the occupants of the rooms. On the other hand, buildings heated by the direct system can be more quickly warmed; hence, it is seldom found necessary to heat these buildings over night, which must always be done, except in very mild weather, in those buildings heated indirectly, which accounts for part of the greater cost of heating indirectly, the remainder being found in the larger heating surface required; but the greater cost is far outweighed by the benefits accruing to health and comfort.

The buildings comprising the University group, and which have to be heated by the three boilers mentioned, are eight in number, as follows: The University building, comprising the college and polytechnic schools, the chemical laboratory, gymnasium, observatory, manual training school (two buildings, school and shops), Smith academy, and museum of fine arts.

To these must be added the Second Presbyterian church, which is heated on Sundays, and also for two evenings during the week, and at irregular times when needed for weddings or funerals.

The University is heated principally by the indirect system, but is supplemented by direct radiators in some of the rooms which have been found difficult to warm. The arrangement consists of small vertical tubular boilers set in brick chambers, which are connected by suitable cold air flues with the outer air, which is conducted under these boilers, passes up through the tubes and around the shell, to the flues leading to the rooms. These boilers are each 8 feet in height by 3 feet in diameter, containing thirty-four 4-inch tubes, making 344 square feet of heating in surface each. The Smith academy and art museum are heated by direct radiation, as is also the gymnasium and the observatory. At the manual training school we have both systems combined, which are so arranged that we can heat either with the exhaust from the engine or with steam direct from the boilers. Here we do altogether the best work; the exhaust from the engine is found sufficient, until the thermometer falls to within 10 degrees of zero for both buildings, when it will serve for one, the other being heated with live steam. The engine is 12 by 12 and is developing about 25 to 30 horse-power running 203 revolutions per minute. The exhaust from this engine does this heating with little or no increase in the back pressure, in fact in very cold weather the back pressure is somewhat less, owing to the rapid condensation, the pipes in the hot air chamber forming a condenser, which proves that with a properly designed system

of piping there need be no loss of power in the engine from excessive back pressure; and I am of the opinion that many establishments now heating with live steam could, with very little expense for alterations, heat with their exhaust that is now wasted, which would make the heating clear gain.

In order to show what our boilers have been found capable of, I introduce a statement of their work during the season of 1884 and 1885. I have selected this season because it was an extremely cold and long one extending from October 1, 1884, to June 10, 1885. The first ten days of June required us to heat some, the temperature being very low for this month, on the 9th falling as low as 52 degrees F. The average temperature for the time stated was 5 degrees F. below the normal. The months of January and February were exceptionally cold, the temperature being on many days below zero, compelling us for 37 days in these two months to keep the steam in all of the buildings the entire 24 hours.

The several buildings comprising the University group were warmed during the season under consideration the following number of hours each.

The University, including the gymnasium, observatory and chemical laboratory	3,051	hours.
Manual training school, both buildings.....	2,510	"
Smith academy.....	1,139	"
Museum of fine arts.....	1,315	"
Second Presbyterian church.....	735	"

Making a total of..... 8,750 hours' work.

The cubic contents and heating surface of these buildings are :

	Cubic contents.	Square ft. heating surface.	Ratio.
University.....	962,004	6,703	1 to 143
Chemical laboratory.....	53,300	344	" 155
Gymnasium.....	154,000	500	" 308
Observatory.....	4,853	42	" 115.5
Manual training school shops	242,000	1,340	" 180.6
" " " school	198,660	2,061	" 96.4*
Smith academy....	465,032	3,500	" 132.8
Museum of fine arts.....	682,350	3,300	" 206.7
Second Presbyterian church.....	500,000	2,025	" 245

Making a total of 3,241,899 cubic feet of space which was heated in the case spoken of by 39,014 bushels of bituminous coal for 216 days, which is 1.038 cubic feet heated by one pound of coal for the entire season.

To do the work required, we frequently burn as high as 2,400 pounds of coal per hour, on 72 square feet of grate surface, $33\frac{1}{2}$ pounds per square foot, which, at 6 pounds of water per pound of coal, gives 14,400 pounds of water evaporated at an average pressure of 45 pounds, the evaporation reaching 6.4 pounds of water per square foot of heating surface. This is heavy duty, I know, but numerous trials have proved that these boilers regularly perform this duty when required.

It was expected, when these boilers were first erected, that we would be able to show, at the end of each day's run, just how much water had been evaporated without the trouble of regular trials. For this purpose the return pipe from each building was fitted with a metre, but they had to be taken out, as it was found that the return of the water was inter-

* This building has the larger heating surface, in order to utilize the exhaust of the engine for heating.

mittent, not flowing until there was sufficient hydraulic head to move the metres; in the meantime, the water in the boilers would get lower than was desirable, so the metres were taken away, and the tank upon which they had been placed was fitted up as a feed water heater, and glass gauges placed upon it, so that the height of water in it could be seen. This tank has been filled a number of times, and the water drawn off and weighed, thus establishing lines, between which is a known weight of water. By this means we can at any time run a trial to ascertain the evaporation.

During the eight years that these boilers have been running several attempts have been made to introduce a smokeless furnace. The first of these was a furnace by B. F. Smith, of Chicago, which was built in March and April, 1880. The arrangement consisted of a sort of basket built out of 2-inch pipes, placed vertically in front of, and connected to the boiler, being enclosed in brick work. The fire was to be forced by a fan blower, the products of combustion passing under the boiler through the opening of the fire doors (the doors being removed), the entire furnace space under the boilers being filled with fire-brick, built up pigeon-hole fashion. After a number of trials and the construction of three different furnaces, this attempt was abandoned, it being a complete failure, as it would not maintain sufficient steam to run the small engine required to drive the fan. This attempt to remove the smoke nuisance cost over \$2,100, which was borne by Messrs. Huse, Loomis & Co., of St. Louis.

The second attempt to introduce a smokeless furnace was made in the spring of 1884, which was a furnace designed by Mr. J. S. Williams, of St. Louis. This furnace was quite an elaborate and complicated affair, contemplating the admission of air by forced draft, both above and below the grate. The air admitted above the grate was expected to be a known measured quantity, gauged to suit the theoretical amount demanded, for the coal fired, which was to be carefully weighed, and fired in small quantities, about 16 to 20 pounds at a time. The delivery of air was to be in sufficiently large quantity to secure perfect combustion when the coal was first fired, gradually decreasing as the coal burned until it reached the incandescent state, when the supply of air would be cut off entirely. This air was also to be admitted in fine streams, just above the fire, at a high velocity, conditions which seemed to meet the requirements for perfect combustion. The furnaces (two), were built in the ordinary furnace space, after removing the fire front with its fixtures, the grates being placed 4 feet 4 inches from the lowest part of the shell of the boiler, a central brick pier pierced with small, round holes on both sides, communicating with an air chamber in its centre, was built, the air-chamber being connected with the blower. This pier also served to support one end of the fire-brick arches which interposed between the fire and shell of the boiler. These arches, or perhaps more properly, series of arches, were fire-brick, in single rows, spaced 2 inches apart, running back from the front about 5 feet. The side walls were also pierced with the small, round holes for the admission of air, the idea being that the air entering from both sides of the furnace, at high velocity and in fine streams, would thoroughly mix with the gases passing off from the coal, and perfect

combustion would be the result. This furnace did give very good results as to being smokeless, but its capacity was so small, and it gave such evidences of being difficult and expensive to operate and maintain, that it was taken out during the following summer. Cost to the University, \$536.28.

The third smokeless furnace tried was the patent of the Backus Furnace Company, of Detroit, Mich. This furnace consisted simply of two fire-brick arches, built in the common furnace, one inside each door, extending inwards $2\frac{1}{2}$ feet, where they had a drop wall 9 inches thick descending to within 9 inches of the grate bars.

This also failed to do the amount of work required of our boilers, by about 40 per cent. This gentleman accepted his defeat in the most graceful manner, paying all the expenses of building and removing his furnace. I may add that we have also tried other devices suggested to us by our own experience and that of others, with the same unvarying result, viz.: Whenever we have admitted air above the grates it has resulted in a loss of capacity, which, in our present condition, we cannot spare.

The cost of the entire steam heating apparatus to the University is as follows :

Land	\$500.00
Boiler house.....	2,873.00
Boilers.....	2,990.00
Setting boilers.....	627.00
Fittings and other appurtenances	233.91
Heaters at University.....	23.12
Setting the same.....	232.60
Heaters in academy.....	2,125.56
Pipe line to University.....	2,550.00
Heaters in manual training school shops.....	1,404.00
“ “ “ “ rooms	1,200.00
Total.....	\$17,048.07

The cost of the heating apparatus in the museum of fine arts I have been unable to ascertain, as this building was deeded to the University complete in every respect by the late Wayman Crow.

SOME EXPERIENCE WITH UNDERGROUND PIPES.

As the several buildings heated from our boilers are some distance away from each other and from the boiler house, the pipe system underground, connecting them with the boilers, forms no inconsiderable part of the whole plant, requiring, as it does, nearly 1,000 feet each of steam and return pipes. From this it will readily be seen that in the eight years these pipes have been laid we have had considerable experience with underground pipes,

The main line to the University is 450 feet long, and has, leading out of it at right angles, three branches 51 feet, 15 feet and 12 feet long, respectively. The line to the manual training school is 314 feet long.

The line to Smith Academy is 90 feet long. The one to the museum of fine arts is 63 feet long. All of these pipes, with the exception of the line to the museum of fine arts, were originally laid in pine boxes made of 2 inch lumber, which were well tarred, both inside and outside. The pipes were wrapped 1st with a sheet of asbestos paper; 2d, with three-quarters of an inch of hair felt; 3d, with a heavy, strong wrapping paper,

the whole securely bound around with strong twine. The intervening space in the box was filled with coke breeze.

The pipes to the art museum were laid in what is called "gutter pipe," which is one-half of the cylinder of sewer pipe. In this case the intervening space was filled with ground charcoal, made into a paste with cement, the whole covered with another half cylinder or "gutter pipe," forming a complete circle, inside of which the pipe was inclosed. There were some short lengths under the floor of the boiler house that were simply plastered over with cement and the brick floor above them carefully grouted with cement, which it was hoped would keep the water from them. These pipes lasted just two years, and when taken up it was found that the expansion had cracked the cement off them, which allowed water filtered through the bricks of the floor to reach them, which the heat of the pipes evaporated, thereby destroying them very rapidly.

These pipes were renewed at the time of the burst, but the following summer the arrangement was changed, so that these pipes were run overhead, where they should have been in the first place; but as this work was done during vacation, when every one connected with the University who knew how such work ought to be done was away, the intelligent (?) pipe-fitter ran things to suit himself.

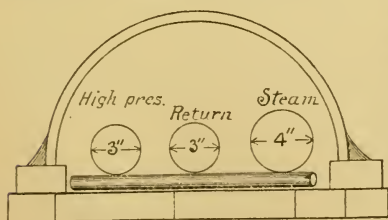
This was the beginning of our troubles, for during the succeeding winter we had to replace the pipes supplying the gymnasium, where it was found that a defective drain had freely supplied the covering of the pipes with water, this covering (as described previously), acting as a sort of sponge, absorbed large quantities of water, thus keeping the pipes wet, which insured their rapid destruction.

During the same winter the heavy oaken boxes built around the expansion bends had to be rebuilt (this time of brick). The heat from the pipes inside of these boxes, with the moist earth outside, rotted them so badly that in the short time of two years they were in danger of caving in. While rebuilding these expansion chambers, it was thought advisable to connect them with the sewer, to drain them, as on one occasion during a heavy rain-storm, the street gutter becoming obstructed, the water ran into the chamber and flooded the pipe boxes. The winter following (1883), the pipes supplying what is known as the physical laboratory wing of the University gave out; here again it was found that the non-conducting covering had hastened the decay of the pipes. The yard through which these pipes are laid not being paved, whenever it rained the water readily found its way through the ground and was soaked up by the covering, which kept them wet much longer than if they had been without covering.

In the winter of 1884 the pipes to the museum of fine arts gave out. From these pipes I had expected long service, thinking that there was no possible chance for water to reach them, but it was found that owing to their being packed tight in the "gutter piping" with the charcoal filling, the expansion and contraction had broken the joint between the two halves of the gutter pipe, thereby allowing the charcoal filling to absorb the moisture from the earth, with the usual result, viz., rapid destruction of the pipes. In the next winter (1885), the pipes supplying the manual

training school failed. Here it was found that the pipe-fitter, with his usual forethought, had run the pipes immediately under some water-closets, so that any overflow from the closets dripped down upon them and although they were covered with a coating of cement the expansion had cracked it so that the water readily found its way to them. Thus burst succeeded burst every winter, until in April, 1887, a burst in the main return pipe (from the University) created considerable anxiety regarding the condition of the whole main line, which up to this time had given no trouble. About 535 feet of the main line is laid in St. Charles street, which is macadamized, and has good drainage, and it was hoped that these conditions had secured to the pipes underlying the street immunity from our enemy, water. This afterwards proved to be the case, as far as we took it up (335 feet), with the exception of about 25 feet immediately underlying a point in the street where the surface had become broken. As the need for a separate pipe to run the various small engines in the physical and mechanical laboratories and elevator pumps had become pressing, it was finally decided to open the street to a point opposite the manual training school, where an attachment could be made to the pipe supplying steam to the engine in that building, which would give these machines steam of the proper pressure, and separate them from the heating system, which was desirable, owing to the fact that we were compelled to maintain such pressure as would run these machines in the heating apparatus, which often resulted in largely overheating the buildings.

It was also decided to renew those pipes that passed through the yard, and as our experience had been adverse to the use of covering around the pipes, owing to its acting as an absorbent, and also to an objectionable smell from it, when wet, finding its way into the buildings. It was now determined to protect it in a different manner. As I am of the opinion that there is no better non-conducting medium than confined air, that was the plan adopted. First, a floor of hard hydraulic pressed brick was laid down in cement, and well grouted in; a single course of brick was then laid along edges of the floor, forming a "stringer." Upon this stringer 21-inch "gutter pipe" was laid, forming an arch over the pipes. The sketch shows a cross-section. All joints and connections were well



cemented. This, it is believed, will keep the pipes dry, but if water should get in it has a chance to run away to the sewer connections in the expansion chambers without wetting the pipes, as they are carried upon rollers $1\frac{1}{2}$ inches in diameter, and the floor is slightly hollowed out in the centre under the rollers.

The cost of protecting these pipes in this manner has been \$1.25 per running foot. The value of the pipes is about \$3 per foot.

As stated heretofore, the pipes in the street were found to be in fairly good condition; the boxing was badly rotted in those parts where it was only a short distance below the surface (about 3 feet at the shal-

lowest part); the top, which had been put on without cross bars under it, was split its entire length, and was crushed in, so that the middle of the boards rested upon the pipes, the edges remaining on the sides of the box. The covering that was around the pipes had also rotted away to a large extent, leaving the upper sides of the pipes uncovered; some portions of it was found in the lower part of the box among the coke breeze which appeared to have been ground down by the contraction and expansion of the pipes until the box was only about half full or slightly less, it being less than half its former bulk, as the boxes when laid were filled to their utmost capacity.

ADDRESS ON RETIRING FROM THE PRESIDENCY OF THE CLUB.

BY WILLIAM B. POTTER, ENGINEERS' CLUB OF ST. LOUIS.

[Delivered December 21, 1887.]

It has of late become a custom in this Club for the retiring President, following the practice prevailing in other and similar associations, to deliver an address—exhibiting as it were a chart of plotted curves representing, almost at a glance, the results accomplished during the year in the various fields of activity in which the Club is interested, or referring to the duties and relations of the workers in these fields, calling attention to tendency of development and to such lessons as may be derived from the exhibit presented.

In the elevated position which he has occupied during the year the presiding officer is supposed to be removed somewhat from the near and narrow view of his own specialties and interests and enabled to scan the wide horizon of the whole profession. It is expected that from such vantage ground he will note, for the benefit of those who have placed him there, whatever is new in knowledge or practice—the new permanent bench marks that appear near the horizon designating ground definitely located; the stakes which mark reconnaissance into new territory and even the prominent objects that faintly appear through the mists of the distant atmosphere and which may serve later on as points of attachment for the advancing lines of survey into the unknown. And besides these there is the progress of the work in older and nearer fields—what has been attempted, what accomplished, as well as the means by which success has been won or failure brought about.

Such a rough sketch of these features as might be presented within the limits of your time and patience must necessarily be too meagre of detail, and with too little contrast in light and shade to form a satisfactory representation of the whole scene for any purpose. On the other hand, to supply a full and complete sketch in any respect worthy of the view—such as might serve as a guide or reference chart—would be somewhat beyond the power of any one to draw with full accuracy. For such a work there would be required a commission composed of skilled workers from each and every department of engineering science.

The task which I have undertaken is a much more modest one. It is

to present briefly a few thoughts that have suggested themselves during the year relating to our own engineer's club—its work and relations with other kindred societies. Let me begin by recalling to your mind a few facts of ancient history. The Club is now nearly twenty years old, having come into existence at a meeting held at the office of the Water-Works Board on November 4, 1863. A permanent organization was effected and officers elected on December 2 of the same year, and on April 12, 1869, the Engineer's Club of St. Louis, Mo., was duly incorporated.

In view of the new interest manifested by the members and the rejuvenation which has of late taken place in the club, it would seem eminently appropriate that on November 4 of next year some fitting celebration should be held to mark the entrance of the Club upon the year of its majority and the new responsibilities which it has assumed. Such a celebration would serve to renew the interest of old time members who have seldom appeared of late years and draw others into the ranks to help the cause who are engaged in various branches of engineering work in and about this city, but have not yet assumed the duties of membership. In the past the Club has offered very few opportunities for its members to become better acquainted than is possible on the more formal occasions of business meetings, and such better acquaintance is likely to prove in some way of mutual benefit to the members themselves as well as promote in a large measure the interests and prosperity of the organization. No more suitable occasion for coming together under favorable auspices and renewing our pledges for the success of the Club could be selected than the approaching twentieth anniversary of its birth; and doubtless such an event would date the beginning of a new and more than ever prosperous era in the history of the Engineers' Club of St. Louis.

The first resolution adopted at the meeting of the founders of the Club in the office of the Water Works Board specified the objects of the club to be the "general advancement of professional knowledge, intercourse, and for maintenance of a library of journals and books of reference." This was more specifically stated in the constitution soon after adopted, which with a few verbal changes made in a recent revision of the constitution and by-laws, now reads: "The objects of the Club shall be the professional improvement of its members and the advancement of engineering in its several branches. Among the means to be employed for the attainment of these objects shall be periodical meetings for the reading of professional papers and the discussion of scientific subjects, the formation of a library, the collection of maps, drawings and models, and the publication of such parts of its proceedings and other engineering matter as may be deemed expedient."

Up to the present time these means provided for attaining the objects of the Club have not been employed to their fullest extent. The periodical meetings are held and valuable papers have been presented; something of a library has been got together, yet much remains to be done to render it as complete and efficient as it might be made; but the collection of maps, drawings and models has not yet been attempted. It is very much to be hoped that arrangements will soon be effected with the

Mercantile Library Association which will insure to the Club the use of a special room in the new library building, where not only meetings may be held, but where the periodicals and books of the Club may be suitably disposed and made easy of access to all its members, and such facilities afforded as shall encourage the establishment of the "collection of maps, drawings and models." In any event it is very desirable that a catalogue be printed, with as little delay as may be, of the books and papers now in the possession of the Club. There is a large amount of valuable and useful material in this collection and some better means of utilizing it should be provided for members.

From the minutes of the early meetings of the Engineers' Club it appears that in lieu of formal written papers, subjects for discussion were presented by a committee appointed for the purpose, most of the members present contributing to the discussion. In some other engineering societies it has been the custom, after the reading and discussion of the regular papers, to devote a part of the meeting to "topical discussion and interchange of data." Something of this kind would, no doubt, add considerably to the interest of our meetings and probably serve to draw out points of interest and value from many who seem loth to prepare written papers or even hesitate to take part in the more formal discussion of papers, and yet are in a way to contribute much that is useful could some inducement be offered.

The organization of the Association of Engineering Societies in 1880 marks an important event in the history of this Club and of the other local societies which have joined the confederation.

The plan which the founders of this Association had in view is a broad and comprehensive one, looking beyond the mere nominal relations now existing and aiming at a confederation in fact as well as in name of all the scattered and diverse elements of the engineering profession, so that by a more united effort the common interest may be better served and higher standards of excellency more surely promoted.

Such a plan is indicated in the avowal at the head of the Articles of Association: "For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies hereto subscribing have agreed to the following articles of association." It has been more definitely stated and its merits very frequently urged by the Board of Managers in their annual reports to the Association. Thus far, however, nothing has been accomplished beyond carrying out what is specified in the first article of association as the "*primary object*," namely, "to secure a joint publication of the papers and transactions of the participating societies." Much benefit has been derived from this joint publication, and it must be said that the work of the Association, so far as it has been developed, is very encouraging. Not only is the Club relieved of many of the inconveniences and annoyances connected with the publication of its own transactions, but members secure by very direct means the most desirable audience for such communications as they have to make and receive in the most convenient and useful form the transactions and proceedings of a large number of prominent engineering societies. The index department is also an excellent feature of the joint publication,

and could not have been so successfully established and efficiently sustained in connection with the publications of any one local society. An appreciation of these advantages has, no doubt, influenced some to seek membership in this Club who would otherwise have felt but little drawn to it, and has been the means of developing a more active interest on the part of others who have long been mere passive supporters. The value of the JOURNAL is likely to increase, too, as the contributing societies gain in strength and usefulness, and as their number is added to, new features may also be developed in time which would add to the interest in the publication, and among others might be suggested reports of discussions of papers and other topics presented. These discussions often contain an amount of pith and point not always found in the papers which excite them, and their omission often seriously detracts from the completeness of treatment which the subjects have received.

The question whether the Association, having successfully accomplished the "primary object" of its existence, can advance another step in the plan for its development and secure any material benefits by a closer union, is one which may well occupy the thoughtful attention of every member of this Club, as indeed of every member of the other societies now forming the Association. I am not unmindful of the fact that at a recent meeting of this Club this question was presented in a recommendation from the Board of Managers submitting a definite plan to secure a closer union, and that after action had been postponed and the subject had been made the special order of business at the next meeting, a most emphatic negative was given. But while this response shows very clearly that this Club is not at present prepared for any closer union with other societies, it should not be considered as the final settlement of this question. If the present Association of Engineering Societies continues, the question will surely be presented again at some time in the future, and it is desirable that each member should prepare himself by a careful and thoughtful consideration of the subject, so that he may decide wisely and upon the true merits of the case,

In my judgment the action recommended by the Board of Managers is premature and if carried out at this time would make the object which they have in view more difficult of attainment than at some later date—not far in the future—when the advantages of a closer union shall have become more prominently developed, and the present objections, mainly due to natural prejudice, and largely local in character shall have diminished in value. That there is a work and an important work which only an Association of Engineering Societies can perform with advantage must even now be apparent. There are many members, but after all only one body, of the profession, and while each member or local society has its own office and work to perform, there are certain functions that pertain to the body as a whole in which each and all the members must be deeply concerned. In attending to the more immediate and pressing local duties, the broader and deeper, though less conspicuous relations, should not be overlooked. In failing to recognize the latter the former may be less efficiently performed. But the Association is, as yet, too young, too immature to accomplish

successfully a work which calls for the exercise of such wisdom and judgment and tact as only come of large experience. In most of the societies composing the Association but little thought seems to have been given to the question of a closer union, and the benefits to be derived from it have not been brought clearly to the minds of the members. Nor has any indication been given as to the nature of this union, and hence no estimate can be formed of its effects upon existing conditions and relations. In addition to these uncertainties concerning the object and character of the change proposed, there is a large amount of inertia to be overcome in the shape of general indifference and local prejudice. Some individuals seem to be satisfied with what they get at present from the Association, in view of the fact that they are connected with other, and perhaps more influential engineering societies. Others appear suspicious that the rights and prerogatives of the other societies may be encroached upon, and still others may be influenced in their desire for a change mainly by a prejudice against these outside societies, and perhaps, also, by jealousy of their supposed influence and exclusiveness.

Sooner or later, however, all such narrow views and local prejudices are likely to be forgotten and the broader and truer relations come more prominently into view. Less sensitiveness concerning the question will prevail because of better knowledge of the proposed change and of its probable effects upon existing conditions. The Association will have gained new strength and influence by the addition of other societies, and those organizations outside of the Association will appreciate that the movement is not inspired by narrow and selfish motives, and that no important principles or privileges need be sacrificed in co-operating with it.

At such a time—and it should not be far in the future—the question of exacting a change in the organization of the Association, to secure *in fact* a closer union, may safely be submitted for discussion, and with the assurance that a wise decision would be reached as the result of an intelligent consideration of the true issues involved.

While, then, the action of the Club at a late meeting declining to favor the recommendation of the Board of Managers was judicious, it seems to me undesirable that the question should be put aside and out of mind as one definitely and finally disposed of in the settled belief that we had wisely decided to attend to our own local affairs and pay no attention to outside interests or relations. It seems to me that there is a work for us to do, and an important one in connection with other engineering societies, and yet not requiring any organic union for its successful accomplishment. Indeed, I believe that if such work were undertaken it would be the means of developing in no uncertain way whatever real benefits are to be gained or evils to result from any closer confederation of societies. The work which I refer to is that of preparing for, and so far as may be, securing the adoption of uniform standards. Surely there is no engineer in any branch of the profession who has gone outside the limits of his own closet but appreciates the evils of the existing *disorder* of things, I might say, in respect of standards employed. I am not unaware of what is being done in the direction of greater uniformity in some of the local societies,

and even in national associations, such as the American Society of Civil Engineers, the Institute of Mining Engineers and the Society of Mechanical Engineers, but, after all, very little has as yet been accomplished and the efforts are somewhat feeble in character and local in effect. An association of engineering societies located in many important centres of the country, consisting of members engaged in all branches of the profession, could certainly do much to secure the uniform adoption of good and approved standards, even if but little was contributed in the way of elaborate comparative tests of various standards under consideration. There is no doubt, however, that many new and valuable data affecting the merits of such standards could be supplied through these agencies. No organic connection of any kind would be necessary for this work. It would only require friendly co-operation in order that the work might be systematically and judiciously arranged, the scattered material carefully collected and critically analyzed, and such experiments properly provided as would supply needed missing data. No one society can expect to bring about very much of the reform that is needed in this direction, but a joint effort on the part of a number, if not of all, would insure the least possible delay, not only in the selection of approved standards, but in their general adoption as well. Why, then, should not the societies forming the Association contribute something to so important a work? By the careful selection and the appointment of appropriate standing committees in each of the participating societies, enabling committees dealing with related subjects to confer together, valuable results are not unlikely to follow, and such as would inure to the benefit of all branches of the profession. The subject is certainly worthy of consideration. It is scarcely necessary to discuss at length any of the many cases calling for treatment in this connection, but it may be well to refer briefly to a few of the more prominent by way of illustration.

The testing of engineering materials is a subject which only needs to be mentioned to prove the necessity of reform. The results of tests of the various materials used in construction are to be found in great numbers, yet in the majority of instances they are not only unreliable but positively misleading. In some cases not even the shape, size or proportions of the test pieces used are given; more often important details relating to the manner of applying the test are missing, while in the vast majority of cases no thought whatever seems to have been given to the mechanical treatment to which the test piece has been previously subjected and yet the results of the test are likely to depend as much upon this as upon any other feature in the case. And though all these points may have been looked after, how difficult to make comparisons when the conditions vary so much in the various methods followed. In the matter of chemical composition, too, if any notice is taken of it, how readily is the determination of ultimate elements accepted when it is upon the proximate composition that the fate of the test piece really depends.

The subject of boiler trials supplies another field very fruitful of confusion and delusion. Of the many trials reported but few will stand the test of critical examination. Some of the necessary data are likely to be

missing and usually it is the all important analysis showing the quality and condition of the coal used and of the ashes and chimney gases resulting from the combustion.

What an amount of time and energy, to say nothing of money and material, might be saved if a uniform system of sizes were adopted in our machine shops and factories. The engineer would be saved much time and trouble in getting out his drawings and specifications, besides securing his work at lower cost; the shop could economize greatly in tools and methods of work, and the duplication of parts would be vastly simplified and secure untold benefits even to the most distant consumer.

These are a few of the many subjects which might be mentioned as calling for some improvement, but they are sufficient to show the needs that are pressing. The task of effecting any substantial reform in these matters is necessarily a great one, but a beginning must needs be made some time—why not now, and through the instrumentality of the organizations composing the Association of Engineering Societies?

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

DECEMBER 21, 1887:—A regular meeting was held at 7:45 P.M. President Rice in the chair. Twenty-four Members and four visitors present.

The record of the last meeting was read and approved.

Mr. Charles E. C. Breck, of Milton, Mass., was elected a Member of the Society.

The following were proposed for membership :

Otis F. Clapp, of Providence, R. I., and Isaac K. Harris, of Lynn, Mass., both recommended by E. L. Brown and Henry Mauley ; D. W. Pratt, of Winchester, Mass., recommended by M. T. Cook and E. W. Bowditch ; and Waterman Stone, of Providence, R. I., recommended by S. E. Tinkham and Henry Manley.

On motion of Mr. Stearns, it was voted : That the Secretary tender to Mr. Arthur V. Abbot, Chief Engineer of the National Super-Heated Water Company, of New York, the thanks of the Society for the very interesting description of the plant of the Boston Heating Company which he gave the Society at its last meeting.

On motion of Mr. Manley it was voted : That the Government be authorized to appoint a committee of five to represent the Society at the approaching meeting of the American Institute of Mining Engineers in this city, and to extend to its members such courtesies as may be found expedient, such expense as the Government may approve to be paid by the Treasurer.

The Secretary read a paper prepared by George A. Ellis, giving a description of the Racine (Wisconsin) Water-Works. A number of photographs were exhibited showing the work in progress and as completed. The paper was discussed by Messrs. Brackett, Manley, Stearns and Tidd.

Mr. M. M. Tidd occupied the rest of the evening, speaking in an informal way of the construction of Dry Docks, with especial reference to the wooden docks built by Mr. Simpson in East Boston and Brooklyn.

[Adjourned.]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

DECEMBER 7, 1887.—282d Meeting :—The Club met at Washington University, at 8:10 P. M., President Potter in the chair, twenty-nine Members and three visitors present. The minutes of the last meeting were read and approved. The Executive Committee reported its meetings of December 5th and 7th, announcing the resignation of Edw. Molitor, and recommending Reno DeO. Johnson, Oscar W. Raeder, James C. Simpson and Albert H. Zeller for election to membership. On being balloted for, all were elected. Applications for membership from the following parties were read and referred to the Executive Committee : I. C. Hubbell, indorsed by C. E. Jones and C. F. White; Robert H. McMath, indorsed by H. G. Tiedeman and Chas. W. Melcher; J. W. Schaub, indorsed by W. H. Bryan and Wm. B. Potter; Jas. M. Sherman, indorsed by M. L. Holman and Geo. W. Dudley.

The Committee on Nominations of Officers for the coming year reported : For

President, M. L. Holman ; Vice-President, J. A. Ockerson ; Secretary, Wm. H. Bryan ; Treasurer, C. W. Melcher ; Librarian, J. B. Johnson ; Directors, Wm. B. Potter and F. E. Nipher. On vote the report was accepted.

The secretary then read his report, which was accepted and ordered filed.

ANNUAL REPORT OF SECRETARY.

Your Secretary begs leave to submit the following report for the year just closed.

There have been fifteen meetings, fourteen regular and one special. Four were held at the Mercantile Library, and eleven at Washington University. The total number of recorded meetings is now 281.

The average attendance at each meeting has been twenty-one. Total attendance of visitors for the year, thirty-seven. The President has been in the chair at thirteen meetings, and the Vice-President at two.

Papers were presented at all the regular meetings. Those contributing were : Chas. F. White, Prof. H. S. Pritchett, Robert Moore, C. W. Clark, C. E. Jones, Prof. F. E. Nipher, J. A. Seddon, Carl Gayler, E. D. Meier, T. T. Johnston, Dr. Wellington Adams, S. B. Russell, H. A. Wheeler and Prof. J. B. Johnson.

In addition, Ex-President McMath delivered an address on retiring, and Prof. C. M. Woodward led a discussion on the Bussey Bridge accident.

Since the last report twenty-three persons have been elected to membership. Twenty having qualified, have been added to our rolls. There have been five resignations and two deaths, a net gain to date of thirteen. Our present membership is 133, recorded as follows : Ninety-six resident, thirty-six non-resident, and one honorary. Three persons elected have not yet qualified. Four applications are to be voted upon, and four more announced, at this meeting.

The records show the existence of the following committees : A Committee of five on Smoke Prevention, Prof. W. B. Potter, Chairman ; a Committee of five on Fire Streams, Robert Moore, Chairman ; a Committee of five on Closer Union of Engineers' Societies, R. E. McMath, Chairman ; a Committee of three on Relations with Mercantile Library, Robert Moore, Chairman.

Respectfully submitted, WM. H. BRYAN, Secretary.

ANNUAL REPORT OF TREASURER.

The Engineers' Club of St. Louis :

GENTLEMEN: I have the honor to submit the following report:

To balance as per report of December 1, 1886.....	\$413.29	
" from unsigned receipts on hand December 1,		
1886.....	42.00	
New receipts issued for dues and initiation fees.....	778.00	
	<hr/>	\$1,233.29
By Vouchers paid.....	\$544.05	
Loans paid.....	75.00	
Receipts cancelled by Executive Committee.....	11.00	
Unsigned receipts on hand... ..	185.00	
	<hr/>	815.05
To balance.....		<hr/> \$418.24
In Provident Bank	105.09	
In St. Louis National bank.....	287.55	
Cash on hand.....	25.60	
	<hr/>	418.24
(Signed)	CHAS. W. MELCHER,	
	Treasurer.	

The report was accepted and referred to the Executive Committee.

The Librarian made a verbal report. There had been no happenings out of the usual line in his department. He mentioned the excellent service the library was doing for students of engineering ; also promised to prepare a list of the Club's literature for the use of the Members. He mentioned having picked up a copy of

Volume I. of the "Transactions of the British Institute of Civil Engineers" which would be accessible to Members of the Club.

Robert Moore, Chairman of Committee on Relations with Mercantile Library reported progress. No definite agreement had been reached as yet, but he felt confident the Club's wants would be fully provided for.

President Potter then read the

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Your Executive Committee takes pleasure in reporting that the year just closing has been one of unusual prosperity. The membership is now larger than at any previous time in the history of the Club, the number on the rolls being 133, seven-teen short of the number entitling the Club to a second representative in the Asso- ciation of Engineering Societies.

Twenty-three applications for membership have been indorsed by the Committee, and the same number favorably acted upon by the Club, one of these newly elected members failing to qualify, while one member has been reinstated. The losses have been five resignations and two by death—Capt. Jas. B. Eads, and Gen. C. Shaler Smith—both distinguished members of the engineering profession, and long honored Members of this Club.

The net gain membership for the year is thirteen.

That a more equitable pro-rating of the annual dues may prevail, your Commit- tee offer the following amendment of the By-Laws for your consideration and adoption :

Resolved, That Section 2 of the By-Laws be amended by inserting after the words "and for non-resident Members, \$4.00," the following : " Members elected after the last meeting in June shall have the option of paying \$4.00 for the cur- rent year and receive the JOURNAL for the whole year, or \$1.00 without the JOURNAL."

The adoption of this amendment, while protecting the Club from loss, would re- move an injustice which some candidates feel when joining the Club during the last quarter.

The interest in the meetings has been well sustained throughout the year as at- tested by the average attendance of twenty-one—an increase of two over the pre- vious year.

The programme adopted in 1886 has been carried out with but slight variation, and the papers presented have proved of much value, eliciting interesting discus- sions upon a variety of engineering topics.

Fourteen papers were read at as many meetings, and nine of these have been approved for publication in the JOURNAL.

Your Committee has approved bills for payment to the amount of \$538.90, as follows:

For the JOURNAL.....	\$399.00	
Printing.....	59.95	
Flowers and memorial (on occasion of the death of C. Shaler Smith)	45.00	
Janitor.....	8.00	
Postage, binding and sundries.....	26.95	
		<hr/>
		\$538.90

The payment of the loan of \$75 on account of the failure of the Provident Bank, and which was outstanding at the beginning of the year, has been authorized and the amount paid by the Treasurer.

The Club decided to vote upon the proposed amendment at the next meeting in the usual way.

P. M. Bruner then read a short paper on "The Action of Frost on Concrete Work." He explained the difficulties met with, and reported the results of a series of experiments he had made on Portland cement; also offered suggestion for

counteracting the influence of low temperatures. He said the addition of salt would lower the freezing point one degree for one per cent. addition up to the point of saturation, and would also increase the tensile strength. The discussion proved very interesting, those participating being Robert Moore, J. A. Seddon, Wheeler, Professor Johnson, Ockerson, Macklind, Flad, Holman, and Caldwell. But little reliable data was to be had. Professor Johnson offered to make a series of tests. It was shown that the best work was secured between the temperatures of 45° and 70° Fah.

[*Adjourned.*]

W. H. BRYAN, Secretary.

DECEMBER 21, 1887—283 MEETING:—The Club met at Washington University at 8:15 P. M., President Potter in the chair, thirty Members and two visitors present. The minutes of last meeting were read and approved. The Executive Committee reported the doings of its meeting of same date, announcing the result of the ballot for officers as follows: President, M. L. Holman; Vice-President, J. A. Ockerson; Librarian, J. B. Johnson; Secretary, Wm. H. Bryan; Treasurer, Chas. W. Melcher; Directors, Wm. B. Potter and F. E. Nipher. The Committee reported that the Treasurer's accounts had been examined and found correct.

The Chair announced the election of the new officers, thanked the Members for their co-operation in furthering the interests of the Club, and then appointed Messrs. Ockerson and Gale a committee to escort the new President to the chair. On taking his seat, Mr. Holman thanked the Club for the honor conferred upon him, and promised to perform his duties to the best of his ability. He then called upon the retiring President for some remarks appropriate to the occasion. Prof. Potter addressed the Club on the present status of the profession and of the Engineers' Club of St. Louis in particular. His remarks were largely historical and he suggested the appropriateness of celebrating the twentieth anniversary of the Club's formation on November 4th, 1888, by a social reunion of some kind. A printed catalogue of the Club's literature was suggested. The benefits resulting from the Association of Engineering Societies and the JOURNAL, with its index department, were referred to. While a closer union of engineering societies might not yet appear desirable, he pointed out a number of ways in which co-operation might result in benefit to all. The question was commended to the thoughtful consideration of the Club.

The following proposals for membership were announced and referred to the Executive Committee: A. W. Hubbard, endorsed by W. H. Bryan and Max G. Schinke; Jos. F. Porter, endorsed by W. H. Bryan and F. H. Pond.

The following amendment having been duly announced was then adopted unanimously:

Resolved, That Section 2 of the By-laws be amended, by inserting after the words, "and for non-resident members \$4," the following: "Members elected after the last meeting in June shall have the option of paying \$4 for the current year and receive the JOURNAL, or \$1 without the JOURNAL."

On motion the Executive Committee was instructed to remit such part of the dues already charged to members elected since June last, as will give them the benefit of the amendment just adopted.

The Secretary then read a paper by Mr. Isaac A. Smith on "Rapid Railway Embankment Construction," being an account of the construction of an embankment in North St. Louis containing 97,500 cubic yards, within a period of sixteen days. The material was river silt and the cost 18.58 cents per cubic yard—but little more than half of the lowest bid received from contractors, none of whom would give a time guarantee. Messrs. Bryan and Wheeler took part in the discussion, in which it was shown that the shrinkage six months after was 11 per cent.

A vote of thanks was given Professor Potter for his address, which was ordered

published. The address was discussed by Professor Johnson, Messrs. J. A. Seddon, Flad and Holman.

Papers by Chas. H. Ledlie and Prof. Chas. C. Brown were announced for the next meeting, Jan. 4, 1888. Professor Engler called attention to an ingenious model of the hyperboloid of revolution.

[*Adjourned.*]

WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

DECEMBER 6, 1887:—The 243d meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and amended inasmuch that Mr. C. L. Strobel should have been designated therein as chairman of committee of which he was nominated a member by the President.

The report of the Committee appointed by the President to take steps toward due recognition of the services of Mr. Morehouse to the Society, and to nominate a successor as Secretary, was presented by the Chairman, Mr. Strobel, and placed on file.

Acting in accordance with report of Committee on the subject, the following resolutions were severally unanimously adopted by the Society :

1. That Mr. Morehouse be elected an Honorary Member of the Society.
2. That a vote of thanks be passed for the faithful services of Mr. Morehouse, extending over a period of 18 years, and of regret for his retirement from office.
3. That a supper be given in his honor on the evening of the next annual meeting.

It was moved and seconded, that the Committee presenting the above-mentioned report be reappointed to make all necessary arrangements for the supper. Carried.

It was moved and seconded that the resignation of Mr. Morehouse be accepted, but that he be requested to present the Secretary's annual report for the current year. Carried.

Agreeably with the nomination of the above-mentioned Committee, L. E. Cooley was elected Secretary of the Society.

It was resolved, on motion, that the Secretary should receive a remuneration of \$25 per month from January 1st, 1888.

L. E. Cooley, as Chairman of Committee on National Public Works reported progress.

The following Committee was appointed by the President to nominate officers for the ensuing year : Messrs. Strobel, Herr and Gottlieb.

A paper was read by Mr. Fiend, on Contouring, and discussed by the Society.

Gen. M. B. Hewson presented a paper, entitled Hints on Drainage, a discussion of which was deferred until the February meeting.

[*Adjourned.*]

JOHN LUNDIE, Secretary pro tem.

ENGINEERS' CLUB OF KANSAS CITY.

DECEMBER 5, 1887 :—A regular meeting of the Club was held at the club-room at 7:45 P. M. There were present Messrs. W. B. Knight, C. E. Taylor, J. A. L. Waddell, T. F. Wynne, B. L. Marsteller, S. A. Mitchell, H. G. Wade, C. H. Talnage, A. J. Mason, W. Kiersted, K. Allen, and six visitors.

The minutes of the last meeting of the Club and of the Executive Committee were read by the Secretary and approved.

The Secretary then read, in the absence of the author, a paper entitled "Devia

tion of the Ship's Compass," written for the Club by Mr. H. C. Pearsons, of Ferrysburg, Michigan.

After a brief discussion it was moved by Mr. Mason that a vote of thanks be extended to Mr. Pearsons for his valuable paper, and to Mr. Kiersted for the paper presented at the previous meeting. The motion was carried.

Mr. Waddell then read some abstracts from a paper on "General Specifications for Highway Bridges of Iron and Steel," describing at length the letting of county bridges, with some defects of methods in use.

Notice was given by the President that the annual meeting would be held December 19.

[*Adjourned.*]

KENNETH ALLEN, Secretary.

DECEMBER 19, 1887:—The first Annual Meeting of the Club was held in the club-room at 8 P. M.

There were present Messrs. Wm. B. Knight, W. H. Breithaupt, T. F. Wynne, J. A. L. Waddell, F. W. Tuttle, C. E. Taylor, Geo. C. Stealey, W. Kiersted, C. G. Wade, K. Allen and 5 visitors.

The minutes of the last regular meeting were read and approved.

Reports of the Executive Committee, Secretary, Treasurer and Librarian were read and approved.

On motion of Mr. J. A. L. Waddell it was voted that for the ensuing year the offices of Secretary, Treasurer and Librarian be united.

Nominations for officers of the Club were made by ballot, with the following results:

President—Wm. B. Knight, J. A. L. Waddell.

Vice-President—Octave Chanute, A. J. Mason.

Director—1. T. F. Wynne, Wm. B. Knight; 2. W. Kiersted, W. H. Breithaupt. Secretary, Treasurer and Librarian—Kenneth Allen, W. H. Breithaupt.

Mr. Fred. B. Tuttle was proposed as Member by Messrs. Wm. B. Knight, C. E. Taylor, F. W. Tuttle.

On motion of Mr. T. F. Wynne it was voted to hold the next regular meeting January 9.

The President presented a subscription list for the signature of those who would participate in a dinner which it was proposed the Club should hold in the near future.

Mr. Waddell read selections from his "General Specifications for Highway Bridges of Iron and Steel," and requested that the Club endorse the objects of the paper.

On motion of Mr. Kiersted it was voted that the President appoint a committee of three to consider the advisability of such action.

Those appointed were Messrs. Chanute, Breithaupt and Mason.

After a few remarks by Mr. Walker, of Cleveland, the Club adjourned.

KENNETH ALLEN, Secretary.

ANNUAL REPORT OF THE SECRETARY AND LIBRARIAN FOR THE YEAR 1887.

To the Officers and Members of the Engineer's Club of Kansas City:

GENTLEMEN: I have the honor to present to you the following report for the year ending December 19, 1887.

The first meeting of the Club was held by seven of our members in the office of Messrs. Knight & Bontecou, January 8, 1887, at which meeting Messrs. Chanute, Waddell and Allen were appointed a committee to draft a constitution and by-laws. These were presented to the Club January 22, and with a few changes were adopted January 29.

At the fourth meeting, February 5, the following officers were elected for the ensuing year:

President, Wm. B. Knight; Vice-President, J. A. L. Waddell; Directors, Octave Chanute, Cliff Wise; Secretary, Treasurer and Librarian, Kenneth Allen.

Thirty-five charter Members had subscribed to the Constitution and By-laws.

Room 19, Dearlort Building, was next secured for the use of the Club, on the first and third Monday evenings of each month, and a book-case bought for the preservation of reports, periodicals, etc.

The Club first met in their room March 7, since which time the following papers have been read and discussed:

March 7, Sewer Gas, by E. B. Kay; April 4, Compressed Air and its Application to the Construction of Foundations, by Wm. D. Jenkins; May 2, Work with Submarine Armor, by G. W. Pearsons; June 6, Railway Work in Australia, by A. J. Mason; October 3, Construction and Operation of the Ninth Street Cable Railway, by M. K. Bowen; November 7, Water Supply and its Development for Small Cities in the West, by W. Kiersted; December 5, The Deviation of Ship's Compasses, by H. C. Pearsons.

Four of these have been printed.

In place of the August meeting the Club took a most enjoyable excursion to Sibley by the kind invitation of Mr. Chanute, 61 ladies and gentlemen participating.

The regular meeting for September was omitted.

At the meeting April 4 it was decided to make application for admission to the Association of Engineering Societies. This was done, and at a meeting of the association in Chicago April 15 and 16 our Club was elected to membership. To defray the extra expense incurred by initiation and dues to the Association, it was voted to amend our By-laws increasing our initiation fee from \$5 to \$5.50, and our annual dues for Members from \$5 to \$8, and for Associate and Associate Members from \$4 to \$7.

Mr. Chanute was chosen to represent the Club on the Board of Management of the Association.

During the year co-operation has been solicited toward the formation of a National Society of Engineers, but no action has been taken.

The Club has also been invited to co-operate with the Council of Engineers on National Public Works, and at the regular meeting, held November 7, the following were appointed by the Chairman to act in conjunction with the Council: Messrs. Octave Chauute, W. H. Breithaupt and Cliff Wise.

During the year there have been held eleven regular meetings.

Attendance.

Members, total.....	122
Members, average.....	11
Visitors, total.....	31

Membership.

	Hon.	Mem.	Assc.	Assc. Mem.
Charter Members.....	0	35	0	0
Additions.....	0	12	0	2
Transferred from Assc. Mem. to Members.....	0	1	0	1
	0	48	0	1
Deceased.....	0	1	0	0
	0	47	0	1
Resignations.....	0	2	0	0
	0	45	0	1

Our Library has made but a small beginning, but already contains a few pamphlets of considerable value. The whole have been catalogued for convenient reference, the list including among others the following transactions of societies: American Society Civil Engineers, 1887, 6 Nos.; Engineers' Club of Philadelphia, 1886-87, 2 Nos.; Rensselaer Society Civil Engineers, complete 4 Nos.; Civil En-

gineers' Club University,* of Illinois, 1887; Engineers' Society Western Pennsylvania, 1887; Illinois Society of Engineers and Surveyors, 1887; Indiana Society of Engineers and Surveyors, 1887; Council of Engineering Societies on National Public Works, 1886.

It includes also the following: JOURNAL ASSOCIATION OF ENGINEERING SOCIETIES, 1887; Reports on Standard Time, presented by the American Society of Civil Engineers; Specifications for Cedar Rapids Sewerage from C. E. Davis; Trautwine's Engineers' Pocket Book, 1887, from J. C. Trautwine, Jr.; Report Philadelphia Water Department, 1886, Report Boston Water Board, 1878-80, Water Supply in Relation to Sanitation, by Col. Wm. Ludlow, two pamphlets on the Tehuantepec Ship Railway, by E. L. Corthell, C. E., from Kenneth Allen. Mr. Chanute has kindly donated a large number of back numbers of *Engineering News* and *The Railway Review*; Mr. Breithaupt of *The American Engineer*; and Mr. G. W. Pearsons has presented photographs of the new water-works at Quindaro.

It is a question in what direction it is desirable to work in order to derive the greatest benefit from a library with our limited means. It would seem unadvisable to expend much money on new works while our facilities for reference are so limited, but I would recommend that a small part of our surplus revenue be applied to the purchase of such standard works of reference as are inaccessible to most of our members on account of expense or otherwise, but which would be appreciated by those engaged in the specialties treated. The selection of such books could be left to the Executive Committee or to a Special Library Committee.

Our exchanges must necessarily be limited from the fact that we cannot return our own publications; but it is asked that those who have reports, public documents, specifications or drawings that would be of interest, notify the Librarian, and they can then be placed in our library, or distributed among those who desire copies. In this way the Club may derive considerable benefit with very little expense

Respectfully submitted,

KENNETH ALLEN,

Secretary and Librarian.

ANNUAL REPORT OF THE TREASURER FOR YEAR ENDING DECEMBER 19, 1887.

Receipts.

Initiation fees.....	55.00	
Annual dues, 1887.....	315.00	
	<hr/>	
	370.00	

Expenditures:

Rent of club-room, 7 mos.	35.00	
Gas bill, 7 evenings	3.50	
Association of Engineering Societies....	99.00	
Book case.....	15.00	
Letter box.	2.00	
Stationery and printing.....	75.00	
Postage.....	13.43	
Sundries, clerical work, etc.....	2.89	
Balance in bank December 19.....	124.19	124.19
	<hr/>	
	370.00	

Bills outstanding.

Initiation fees.....	22.00	
Annual dues, 1887.....	49.00	
	<hr/>	
	71.00	
Sundry expenses, rent, postage, etc., about.....	8.00	63.00
	<hr/>	
Net assets about		187.19

Respectfully submitted,

KENNETH ALLEN, Treasurer.

INDEX DEPARTMENT.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles and special engineering reports of general interest and value. It is printed on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book.

Accidents for October. Summary of railroad accidents with causes. *R. R. Gaz.*, Nov. 25, 1887.

Address to the Institution of Civil Engineers. Gives the address of Geo. B. Brace on assuming the President's chair. A general review of engineering. *Engineer*, Nov. 11, 1887.

Arches, Stone. Discusses the problem of the stone arch as designed from the catenary curve. *Eng. News*, Nov. 19, 1887.

Anemometers. *Experimental Investigations and Description of the Hagemann Anemometer.* By G. A. Hagemann. Translated by G. E. Curtis from the "Annuaire Météorologique" of the Danish Meteorological Institute, Copenhagen, 1877. *Journal of the Franklin Institute*, Sept., 1887, Vol. CXXIV., No. 741.

Bessemer Steel. *Modifications of the Process.* Abstract of a lecture before the Franklin Institute, Jan. 3, 1887, by C. Hanford Henderson. Treats especially of the Clapp-Griffiths and the Thomas and Gilchrist methods. *Journal of the Franklin Institute*, June, 1887, Vol. CXIII., No. 738.

Bridge, Forth, Erection of. By A. S. Biggart. A paper before the British Association, treating of the problems that occurred during the erection of the Forth bridge and methods of overcoming them. Illustrated. *Engineer*, Nov. 25, 1887.

—, *Ravine Lowestoft.* Description, with elevation and details, of a wrought-iron arched bridge. The arch ribs are made of $\frac{1}{4}$ -inch web plate and angle iron. *Engineer*, Sept. 2, 1887.

—, *Three-Hinged Iron Arch.* By J. H. Cunningham. Gives description, with details, of a three-hinged, wrought-iron arch constructed at Claremont, Ia. *Engineer*, Aug. 12, 1887.

—, *Torkham, India.* Describes the method employed to launch three short spans of riveted girder of Torkham bridge. Illustrated. *Indian Engineering*, Oct. 1, 1887; *Eng. News*, Nov. 19, 1887.

—, *A New Truss.* By Geo. H. Pegram. Proposes a new form of truss. Gives formulas and applies them to a through span of 235, etc. Valuable. *Eng. News*, Dec. 10, 1887.

Blowers, Experiments and Experience with. By H. I. Snell, before the Philadelphia meeting of the American Society of Mechanical Engineers. *Am. Engr.*, Nov. 23, 1887.

Boilers, Water Tube. Discussion on their uses and drawbacks. *Engineer*, Oct. 7 and 28, 1887.

—, *Use of Kerosene in Steam Boilers.* Account of its successful use in preventing and removing incrustation; from a paper by Mr. L. F. Lyne, before the American Society of Mechanical Engineers, Philadelphia. *Power*, December, 1887.

BOOKS FOR ENGINEERS.

NEWMAN, JOHN. Notes on Concrete and Works in Concrete. Especially written to assist those engaged upon works. The result of many years practical experience. 38 pages, 12mo, cloth, \$1.50.

DYE, F. Hot Water Supply : A practical treatise upon the fitting of hot water apparatus for domestic and general purposes. 81 pages, 12mo, cloth, \$1.00.

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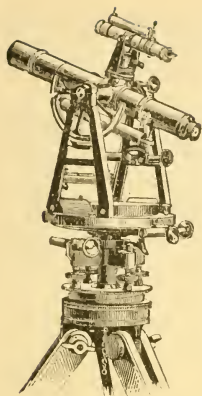
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54 SACRAMENTO STREET, CAMBRIDGE, MASSACHUSETTS.

- Brake Tests, Westinghouse.** Gives details of the test made at Weehawken with a train of 50 empty freight cars. *Eng. News*, Nov. 26, 1887; *R. R. Gaz.*, Nov. 25, 1887; *Nat. Car and Loc. Builder* for December, 1887. Gives table of the tests at various places.
- Buildings, Steel Plate.** Detailed plans and descriptions of a method of constructing buildings with embossed galvanized steel plates. *Sci. Am. Supple.*, Nov. 5, 1887.
- Cable Roads, Edinburgh.** Gives constructive details of the Edinburgh Northern Cable Tramway, with description. *Engineer*, Oct. 28, Nov. 4 and 11, 1887.
- Cables, Steel.** Abstracts from the specifications for the steel cables for Birmingham cable roads. *Engineer*, Aug. 12, 1887.
- Car Axles, Bearings and Lubricants.** Summary of the discussion of the above subjects by the New England Railroad Club. *Railroad Gazette*, Nov. 18, 1887; also *Nat. Car and Loco. Builder*, December, 1887.
- Car Heating, Couplers for Steam.** Brief descriptions with drawing of nearly all the different forms of coupling now in use for continuous heating of cars by steam from the locomotive. *R. R. Gaz.*, Dec. 2, 1887.
- , *Gold System.* Gives illustrated description of the Gold system adapted to the Baker heater. *Railroad Gazette*, Dec. 16, 1887.
- , *Lighting and Ventilation.* Discussion of the above subjects by the New York Railroad Club. *Railroad Gazette*, Nov. 25, 1887.
- Casting, New Process of Making Ornamental Castings.** Consists in lining the inside of the mould with carbonized lace or other textile fabric. Abstract of remarks made at the meeting of the Franklin Institute, April 20, 1887. By A. E. Outerbridge, Jr. *Journal of the Franklin Institute*, June, 1887, Vol. CXXIII., No. 738. Report of Franklin Institute Committee on same. *Journal of the Franklin Institute*, November, 1887, Vol. CXXIV., No. 743.
- Cement, Portland, Improvements in the Manufacture of.** By Frederick Ransome. A paper before the British Association, giving the latest and most advanced method of manufacture. *Engineer*, Sept. 9, 1887, *Sci. Am. Sup.*, Nov. 19, 1887.
- , *Ransome's Improvements in the Manufacture of Portland Cement.* By R. J. Friswell. Re-printed from the London *Engineer*, March 4, 1887. *Journal of the Franklin Institute*, June and July, 1887, Vols. CXXIII., CXXIV., Nos. 738, 739.
- Chimney.** Gives notes on the construction of a large chimney, being an iron frame lined with brick. *Sci. Am. Supple.*, Dec. 10, 1887.
- Coal Conflagration at Kidder's Slope.** By Martin Caryell. Gives details of the conflagration in the mines and the methods adopted to put it out. *Trans. Am. Soc. C. E.*, Vol. III., pp. 147-154.
- Columns, Experiments upon Z Iron.** By C. L. Strobel. Abstract from a paper before the American Society of Civil Engineers, giving results of tests upon 15-inch Z iron columns. *San. Eng.*, Dec 3, 1887.
- Combustion.** A good article for practical men. *Engineer*, Aug. 19, 1887.
- Coast Defenses of the United States** A summary of the reports to the Secretary of War, of General Duane, Chief of the Engineer Corps, and General Benet, Chief of Ordnance for the army. *The Railroad and Engineering Journal*, December, 1887.
- Crane, Traveling.** An illustrated description of a traveling crane, 50 feet span, to lift three tons. *Engineer*, Sep. 9, 1887.
- , *Traveling.* Gives a description with full details of a six-ton universal traveling crane for the erection of the Union Elevated Railroad, Brooklyn. *San. Engr.*, Dec. 17, 1887.
- , *Water, for Indian Railroads.* Gives brief description and full detailed drawing of water cranes to be used on the Indian State railways. *Engineer*, Oct. 7, 1887.
- Dam, Failure of the Mill River.** Gives report of a committee appointed to report upon the failure of a dam on Mill River, at Williamsburg, Mass. *Trans. Am. Soc. C. E.*, Vol. III., pp. 118-122.
- Disinfecter, Aero Steam.** A disinfecter in which all articles are subject to a moist heat of at least 212° Fah. *Engineer*, July 29, 1887.



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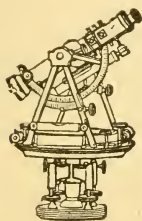
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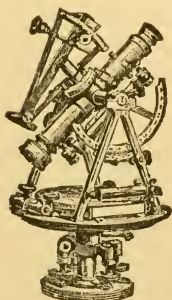
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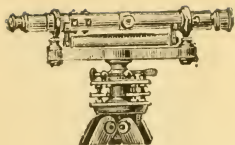
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- Dry-Dock, Havre.** Full description, with plan, transverse section and views of the work of the large dry-dock being built at Havre, France. *Le Genie Civil*, Oct. 29, 1887; *San. Eng.*, Dec. 3, 1887.
- Drainage, Newhaven.** Brief description, with details, of the drainage work at the Port of Newhaven, Eng. *Engineer*, July 29, 1887.
- Draw-Bridge, Milwaukee.** Description of a 205-foot span double-track draw-bridge at Milwaukee. Cuts showing details. *San. Eng.*, Nov. 26, 1887.
- Draw-Spans and their Turn-Tables.** By C. Shaler Smith. A paper for "non-specialists," showing method of computing the strains; also, gives table of draw-bridge tests to obtain co-efficient of rolling friction. *Trans. Am. Soc. C. E.*, Vol. III., pp. 129-141.
- Dynamo-Electric and Electro-Dynamo Machinery, Design and Construction of.** Read before the Engineers' Club of St. Louis, Feb. 16, 1887, by Dr. Wellington Adams. Applies the formulæ of Kapp to the design of an efficient dynamo. *The Electrician and Electrical Engineer*, Dec., 1887.
- Electric Light for the New Cruisers** Paper read before the National Electric Light Association by Lieut. J. B. Murdock, U. S. N., presenting in a general way the views of the Bureau of Ordnance of the Navy Department on the peculiar conditions to be met in the lighting of ships, and the best methods of meeting them. *The Railroad and Engineering Journal*, Oct., 1887.
- **Lighting of Passenger Trains.** Paper read before the American Institute of Electrical Engineers at its June meeting in New York, by G. W. Blodgett, Electrician of the Boston & Albany Railroad. Describes various methods, especially that in use on to B. & A. Railroad, employing storage batteries. *The Railroad and Engineering Journal*, Oct., 1887.
- **Meter.** A practical, current meter, the invention of Prof. George Forbes, described by him before the American Institute of Electrical Engineers, Oct. 11, 1887. Illustrated. With interesting discussion. The meter is very simple, and works on the principle of a smoke-jack by a current of heated air rising from a coil. *The Electrician and Electrical Engineer*, Nov., 1887.
- **Forbes'.** Description of various forms and analysis of patent claims. By Prof. Edwin J. Houston. Also paper by Prof. George Forbes, describing his electrical current meter, read before the Franklin Institute, Oct. 19, 1887. *Journal of the Franklin Institute*, Dec., 1887, Vol. CXXIV., No. 744.
- **Motors.** An exposition of the principles with especial reference to the Sprague system. Presented to the U. S. Naval Institute, May 16, 1887, by F. J. Sprague. *Proceedings of the U. S. Naval Institute.* Vol. XIII., No. 3.
- **Street Cars, Methods of Gearing for.** Paper read before the American Institute of Electrical Engineers, Sept. 20, 1887, by A. Reckenzaun, C. E. Compares different methods of gearing in use, and advocates the use of worm-gearing. *The Electrical World*, Oct. 1, 1887.
- **Current to Produce Adhesion.** By E. E. Ries. Gives results of experimental examination of the electric current as a means of increasing the tractive adhesion of railway motors and rolling contacts. *Sci. Am. Suppl.*, Dec. 10, 1887.
- Electricity, Modern Views of.** Extracts from lectures by Dr. Oliver Lodge in London and Birmingham. Not published before. *Engineer*, Nov. 4, 1887.
- **as a Motive Power.** By Wm. Wharton, before the Philadelphia Street Railway Convention. Gives a full review of electricity as applied to the propulsion of street-cars, with figures of expense and practical details. *Sci. Am. Suppl.*, Dec. 3, 1887.
- **Its Production Direct from Fuel by Edison's Pyromagnetic Dynamo.** Paper read before the American Association for the Advancement of Science, New York. By Thomas A. Edison. *The Railroad and Engineering Journal*, October, 1887.
- **in Mills, Various Uses for.** By C. J. H. Woodbury. Mentions briefly various applications of electricity to purposes other than lighting. *The Electrician and Electrical Engineer*, November and December, 1887.



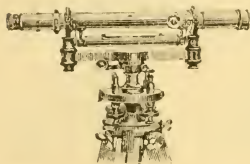
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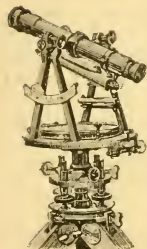
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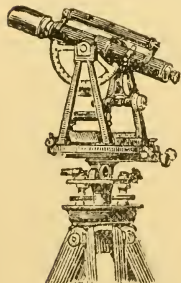
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- Engine, Compound.** Illustrated description of an engine exhibited at the Rouen Exhibition and now in the Loubardemont flour mills. *Engineer*, July 15, 1887.
- , *Benier's Hot Air.* Description of the above engine, with plan, sectional elevations and sections. *Engineer*, Nov. 4, 1887; *Sci. Am. Supple.*, Dec. 10, 1887.
- Engines, Compound Vertical.** Detail drawings, fully dimensioned, of all the parts of the engines for the Indian State Railway. *Engineer*, Sept. 2, etc., 1887.
- , *Compound Pumping.* A two page plate showing the engines and pumps of the Southwark and Vauxhall Water Company and other engravings, giving engine details. Engines are inverted double-cylinder compound direct-acting rotative. *Engineer*, July 22, etc., 1887.
- , *Pumping, Umari Colliery.* Gives abstracts from the specification for the construction of a colliery plant in India. Illustrated. *Engineer*, Aug. 19, 1887.
- , *Pumping.* Illustrated description of a new form of pumping engine for Champagne, Ill. It is a vertical compound duplex direct double-acting pump, with outside flanges. *Eng. News*, Nov. 26.
- , *Triple Compound.* Perspective view of a set of triple expansion engines and specifications to which they were built. *Engineer*, Aug. 26, 1887.
- , *Triple Expansion.* Sectional elevation and perspective views of the triple expansion engines of the Italian cruiser "Dogali." *Engineer*, Aug. 5, 1887.
- , *Triple Expansion.* By Wm. M. Henderson. A paper before the Franklin Institute describing Henderson's improved triple expansion engines. Claims to have the fewest possible number of parts. *Sci. Am. Supple.*, Nov. 26, 1887.
- , *Steam Report of the Steam Engine Tests* made at the Franklin Institute Electrical Exhibition at Philadelphia, in 1884. Very complete tests of Porter Allen, Southwark, and Buckeye engines. *Journal of the Franklin Institute*, Feb., 1886, Vol. CXXI., No. 722.
- , See Governor, the Ball
- Estuaries, Tidal, and the Bar of Mersey.** By W. H. Wheeler. Gives a general discussion of two papers read before the British Association. *Engineer*, Nov. 11.
- Explosives, Composition of High.** Gives interesting list of the composition of high explosives. *Le Genie Civil*, Oct. 22, 1887; *San Engr.*, Nov. 26, 1887.
- , *Roburite.* Gives results of experiments in mining coal with roburite. *Engineer*, Oct. 28, 1887; *Sci. Am. Suppl.*, Nov. 19, 1887.
- , *A New.* Gives some of the characteristics and properties of a new explosive called Emmensite, said to be better than dynamite. *Am. Engr.*, Nov. 23, 1887.
- Extension, Elastic.** By R. H. Graham. Gives a mathematical treatment of the subject of elasticity. Considers it a form of motion and subject to the laws of velocity and acceleration. *Engineer*, Aug. 19, 1887.
- Flexure, Resistance of Beams to.** By J. G. Barnard. An abstract from a paper on the resistance of materials, by M. Decamille, with comments. *Trans. Am. Soc. C. E.*, Vol. III., pp. 123-128.
- Filter, Warren Water.** Description of the Warren water filter, with plan and sections. *Eng. News*, Nov. 19, 1887.
- Floor Beam, Test of.** Abstract from a paper by A. P. Boller before Am. Soc. of C. E., giving details of the testing of a full size, wrought-iron, double-track floor beam. *San. Eng.*, Dec. 10, 1887.
- Flooring, Steel.** Gives description, with illustrations showing its application, of Lindsay steel flooring. *Engineer*, Oct. 7, 1887; *Eng. News*, Nov. 26, 1887.
- Flow of the West Branch of the Croton River.** By J. J. R. Croes. Gives details of the rainfall and gauging of the west branch of the Croton River from 1866-72. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., pp. 76-86.

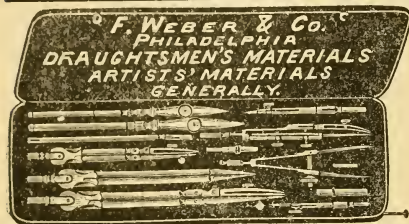
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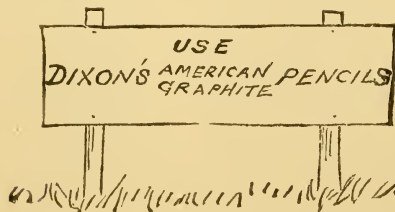
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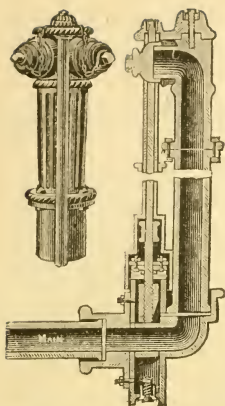
- Foundation, Method Pursued in Replacing a Stone Pier on a Pile** By J. A. Monroe Gives description of the method employed to replace on the pile foundation a grillage with two courses of masonry, which had broken loose and settled 14 inches out of place. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., p. 59.
- Foundations for the Brooklyn Anchorage of the East River Bridge.** By T. Collingwood. Gives details of method of construction adopted. *Trans. Am. Soc. C. E.*, Vol. III., pp. 142-146.
- Heating Plant, Boston.** Illustrated description of the plant of the Boston Heating Company. *Eng. News*, Nov. 12, 1887.
- Hydrant Service, Rental Value of.** By C. E. Chandler before the Connecticut Association of Engineers and Surveyors. *Eng. News*, Nov. 19, 1887.
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- Indicators.** An interesting paper by Chas. E. Emery, before the American Society of Mechanical Engineers, showing the necessity of taking diagrams from the steam-chest at the same time as from the cylinder. Gives actual diagram. *Am. Engr.*, Dec. 7, 1887.
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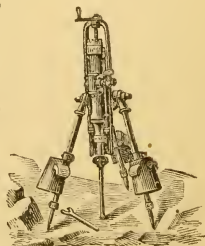
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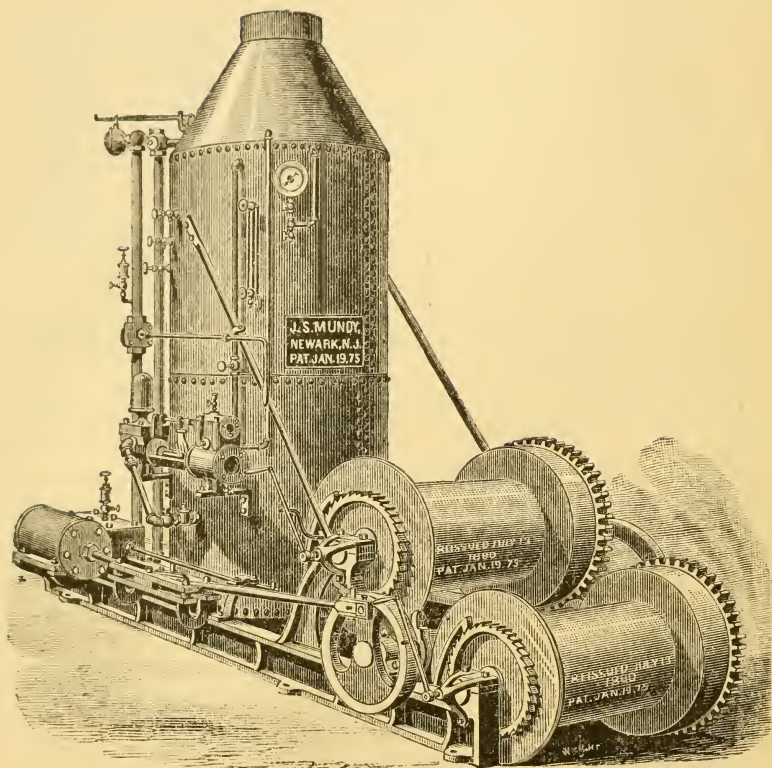
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- Roof, Bandora Station.** Brief description with detailed drawing of a roof truss for Bandora station, India. *Engineer*, Dec. 2, 1887.
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- Sanitation of Towns.** By J. Gordon. A presidential address before Society of Municipal and Sanitary Engineers and Surveyors of England. *Sci. Am. Suppl.*, Nov. 19, 1887.
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- , *Leicester.* Specifications for the erection of pumping engines, etc., for the Beaumont Lego pumping station, Leicester. *Engineer*, Aug. 12, 1887.
- , *Luton.* Brief description of the Luton, Eng., sewerage farm. *Engineer*, Nov. 18, 1887.
- Sewers, Memphis.** By Rudolph Hering. Gives conclusions arrived at from a recent inspection of the Memphis sewerage system. *San. Engr.*, Nov. 24, 1887.
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- Steel, Compressive strength of iron and.** By C. A. Marshall. Gives results of a large number of tests made to discover the relation which compressive strength bears to tensile strength. *Trans. Am. Soc. Civ. Engrs.*, Vol. XVII., pp. 53-110 (August, 1887).
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- Storage Batteries for Electric Locomotion.** By A. Reckenzaun. A paper read before the Electric Light Association. Gives historical facts and working figures of expense, etc. *Sci. Am. Supple.*, Nov. 5 and 19, 1887.
- Struts, Working Strength and Stiffness.** By Prof. W. H. Smith. *Engineer*, Oct. 14 and 28, 1887.
- Tests, Material.** Gives the tests that material supplied for locomotives on the Missouri Pacific Railroad must stand. *Nat. Car and Loco. Builder*, December, 1887.
- Ties, Metallic.** Gives figures showing the cost of maintenance of track laid with metallic ties. *R. R. Gaz.*, Dec. 16, 1887.
- Train Service, American and Foreign.** By A. T. Hadley. Gives a comparison of the train service in the different countries. Shows the average frequency of trains and the proportion between train service and population. *R. R. Gaz.*, Nov. 25, 1887.
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- Viaduct, New Tay.** By S. S. Kelsey, before the Institution of Mechanical Engineers. Gives full description of the new Tay viaduct and some of the methods employed in its erection. *Engineer*, Sept. 2, 1887.
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- Water-Pipes.** By A. H. Howland. Treats of the different kinds of pipes, their qualities and availabilities. *Proc. Phila. Engrs. Club*, Vol. VI., p. 55; *Am. Engr.*, April 20, 1887; *Sci. Am. Sup.*, Feb. 12 and Nov. 5, 1887.
- Water Supply, The Tansa, of Bombay.** By K. Hedges. Gives details of the work in progress to give the city of Bombay a supply of 60,000,000 gallons per day. Gives profile of dam to be 8,500 feet long and 118 feet in height. *Engineer*, July 15, 1887.
- Water-Works, Cohasset, Mass.** Brief description of the Cohasset, Mass., water works. With plan showing arrangement of wells, collecting chamber, etc. *San. Engr.*, Dec. 3, 1887.
- , *Dover, N. H.* Report of Mr. P. M. Blake to the Mayor of Dover on the sources of water supply available for the city. Gives detailed estimate of cost. *Eng. News*, Nov. 26, 1887.
- , *Southwark and Vauxhall.* Full description with details of pumping engines, etc. *Engineer*, July 3, etc., 1887.
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PRESENT ASPECT OF THE PROBLEM OF AMERICAN INTER- OCEAN SHIP TRANSFER.*

BY ROBT. MOORE, MEMBER OF THE ENGINEER'S CLUB OF ST. LOUIS.

[Read March 2, 1887.]

Since the cutting of the Isthmus of Suez by the canal opened in 1869, the greatest remaining obstacle to the world's commerce is that offered by the isthmus joining the two continents of North and South America. So great is this barrier to the commerce of the New World especially, that the voyage from New York to San Francisco is increased by it from less than 5,000 to nearly 15,000 miles, or more than three times what it might otherwise be.†

Against this obstacle the world has chafed uneasily ever since it first blocked the way of Columbus in his search for the Indies. For many years, indeed, men refused to believe in the reality of its existence, but made diligent search for the strait which they felt sure nature must somewhere have left as a passage-way between the two continents. Nor was this belief abandoned until, after repeated search, Cortez finally, in 1532, proved the continuity of the isthmus, and the unreality of the long-sought strait.‡

But the hope of establishing a highway, which, in the words Emperor Charles V., "should connect the eastern and western shores of the New World, and shorten by two-thirds the route from Cadiz to Cathay," was not at once abandoned. The middle of the sixteenth century had hardly passed before we find the Spanish historian, Gomarra, suggesting that what nature had left undone should be done by art, and calling attention to the three routes that are most prominent to-day, viz. : Tehuante-

* Prepared by request for the "Round Table," St. Louis, and read to them January 8, 1887.

† The exact figures are 4,871 and 14,840. See Sullivan on Interoceanic Communication by Way of American Isthmus, pages 239 and 212.

‡ Sullivan, page 10.

pec, Nicaragua and Panama. Addressing Philip II. of Spain, son of Charles V., he says :

“It is true that mountains obstruct these passes, but if there are mountains there are also hands. Let but the resolve be made, there will be no want of means * * * To a King of Spain, with the wealth of the Indies at his command * * * what is possible is easy.”*

To these brave words, however, Philip turned a deaf ear. He was too full of plans to crush out heresy in his dominions, to give attention to matters of this kind, and fearing, also, lest easier means of communication might lead other nations to contest the Spanish hold upon Peru, he forbade any further pursuit of this great end, upon pain of death.

The scheme, put thus violently to rest, slept almost undisturbed for two centuries and a half. One of the first to awaken it was Humboldt, whose interest in the subject had been aroused by his extensive travels in South America and Mexico, and who, in 1808 again called the attention of the world to this important problem, and suggested its solution by way of the Gulf of Darien and the Atrato River.

A further and very powerful impetus to the discussion was given fifteen years later (1823) by the revolt and independence of the Central American States, which have since then been almost unceasing in their efforts to enlist the aid of foreign capital and more potent states in the task of cutting the Isthmus. To this end, franchise after franchise has been granted, now to Dutchmen, now to Frenchmen, and then to Americans : but, up to the year 1850, beyond two surveys at Panama and one at Tehuantepec, nothing whatever was really done.

At this time, however, events occurred which so greatly deepened the interest of the United States in overcoming the isthmian barrier, that something practical was at last accomplished. These events were the acquisition of California by the United States, and the gold discoveries of 1849, by which the traffic across the isthmus was so greatly increased that some better means of transport than the old Spanish highways afforded, became a matter of necessity. Out of this necessity came the establishment of a line of American steamboats on the San Juan River and Lake Nicaragua. But a far more important result was the construction, during the years 1849 to 1855, of the Panama Railroad, the work of American engineers and American money.

But while the establishment of these improved means of communication relieved in part the most pressing wants of traffic, they seemed only to increase the desire for some further means by which not only the cargoes but the ships themselves should be taken safely from ocean to ocean. The decade 1850 to 1860 was signalized by a number of surveys, by which nearly every route which offered any hope of success was explored and its essential features correctly developed. Among these may be mentioned the survey of the Tehuantepec route under General Barnard, that of Nicaragua by Colonel Childs, the ill-fated and almost fruitless expedition of Lieutenant Strain from Caledonia Bay, and the surveys of the Atrato route by Trautwine, and later by Lieutenants Michler and Craven—all Americans—besides several others, by citizens of other countries.

* See Sullivan, p. 11, but the date 1551, there given, is incorrect, as Philip did not ascend the throne until 1555.

Our civil war interrupted the progress of these investigations, though it did not wholly stop them, a survey of the San Blas route, under the auspices of Mr. Kelly, of Philadelphia, having been made in 1864. But as soon as the war was over interest in the subject began to revive. One of the first signs of this renewed interest is the report of Admiral Davis, U. S. N., of July 10, 1866, in which, in obedience to a resolution of the United States Senate, he presents maps of all the lines and sums up what was then known about them.

As a result of the discussion following this report the Government of the United States, in 1870, soon after the accession to the presidency of General Grant, and largely through his influence, authorized a series of official surveys of all the isthmian routes, for the purpose of fully and finally determining their respective merits. These surveys were placed in charge of the Navy Department, and under the general direction of Admiral Daniel Ammen, whose interest in this subject was of many years' standing, and who was at the time chief of the Bureau of Navigation. They were intended to embrace every route that offered any prospect of success, and they finally included surveys of Tehuantepec, Nicaragua, Panama, San Blas, Caledonia Bay and several variations of the Atrato route, so that the whole ground was very thoroughly covered. The results of all the surveys were then submitted for examination to a special board, composed of General Humphreys, Chief of U. S. Engineers; Mr. C. P. Patterson, Superintendent of the U. S. Coast Survey, and Admiral Ammen, who, after a very careful study of the whole subject, extending over four years and including the re-examination in the field of some of the lines, finally, in 1876, gave their unanimous verdict in favor of the Nicaragua route.

The surveys since made at Tehuantepec, under Captain Eads; at Nicaragua, by Mr. Menocal, of the United States Navy; and at San Blas and Panama, under the auspices of Wyse and de Lesseps, bring us down to the present time, and, as the result of all, the same three routes that were mentioned by Gomarra more than three hundred years ago stand out pre-eminent to-day as those between which our choice must lie, to wit, Panama, Tehuantepec and Nicaragua.

Let us, therefore, consider briefly the characteristic features of each of these routes, and see if we can find reasons for determining a choice between them, taking up first

THE ROUTE BY PANAMA.

As is well known, the first practical attempt to solve the problem of interoceanic ship transfer is the canal now in progress across the Isthmus of Panama, under the presidency of Count Ferdinand de Lesseps, to whose efforts the world owes the construction of the canal across the Isthmus of Suez.

The company under which this work is being done, known as "La Compagnie Universelle du Canal Interoceanique de Panama," was definitely organized in 1881 as the legal successor and assignee of a preliminary company ("Société Civile"), formed in 1876, by Lieut. Lucien Napoleon Bonaparte Wyse, of the French Navy, to whom was granted in May, 1876, by the United States of Columbia, a concession to construct a ship canal across the isthmus on any line to the south and east of capes

Tiburon and Garachine. The reason for this limitation of the franchise was, that the territory to the north and west of this line was already included in the grant to the Panama Railway Company. Some hurried examinations on the ground having satisfied the grantees that no practicable route could be found east of the line named, they succeeded, in May, 1878, in getting their concession amended so as to include the territory within the Colombian domain west of this line, subject, of course, to the prior right of the railway company.

A hasty survey, hardly deserving the name, having meantime been made of the route via Panama, by Commander Reclus, of the French Navy, Messrs. Wyse & Co. were now ready for the most important step of all—to them, at least—that of raising the money. But the typical Frenchman is very cautious about parting with his money, and success in raising the large amount needed for a work such as this was possible only upon the condition of enlisting the aid of some one who should bring to the enterprise the prestige of success in works of this kind, which was equivalent to saying that they must put at their head the name of Ferdinand de Lesseps.

This, therefore, was now done, in pursuance, no doubt, of a prior understanding, and the enterprise has since then been known to the world as that of de Lesseps only. A contract was entered into, though it was not formally executed until somewhat later (July 11, 1879), by which de Lesseps agreed with Wyse & Co. to organize a canal company, of which he should be the president. This new company were to take over the franchise held by Wyse & Co., and to pay them for it the sum of ten million francs (\$2,000,000), half in money and half in stock of the company, bearing, as does all the stock, five per cent interest from the date of its issue.

The next step was to call an "International Scientific Congress" of engineers and others, citizens of France and foreign countries, whose judgment in such a matter should carry weight, to indorse the plans of Wyse & Co. for a canal at Panama before making their final appeal to the public for money. This was the method of procedure already followed successfully at Suez, and throughout the whole course of the present enterprise it will be found that every step taken is but a repetition of one already taken in connection with the former scheme. The congress thus called assembled in Paris, May 15, 1879. It numbered 135 persons, of whom nearly half were foreigners, including a number of able men, whose special knowledge fitted them to discuss the matter intelligently in all its bearings. But the majority were Frenchmen, who could hardly be expected to oppose The "Great Frenchman" in anything, whilst no less than one-tenth of the whole number were directly under him as employés of the Suez Canal Company. An effort to secure consideration for other routes than Panama was promptly suppressed, and the whole discussion of route, plan, and estimates of cost crowded into two weeks, at the end of which time the Congress, by a majority vote (a large number, however, not voting at all), gave de Lesseps the indorsement that was sought for, and adjourned.*

* See the interesting book of J. C. Rodrigues, on "The Panama Canal," pages 53 and following.

The preliminary steps were then at once taken to organize the Universal Company, and an appeal was made (July 23, 1879) to the public to subscribe for 800,000 shares of stock of 500 francs each, or \$80,000,000. The public responded, however, to the extent of 160,000 shares only, or but one-fifth of the amount required. Not caring to begin with so small a sum, de Lesseps declared the whole subscription off (August 19, 1879), and returned to the subscribers their deposit money.

The most probable reasons for this failure were a want of confidence in the estimates of cost, and a fear of hostility to the enterprise on the part of the United States, of which there had been some manifestations in Congress. De Lesseps, therefore, with characteristic energy, at once took up the task of removing these obstacles, and, with this purpose, announced his intention of shortly going himself to the isthmus with a corps of engineers to verify the work of Wyse and Reclus, of proceeding thence to the United States, to convince the American people that there were no good reasons for their hostility, and of making on his return to France a second appeal to the public for financial support. To this programme he adhered with great fidelity, going in December, 1879, to Aspinwall with his family and a suite of sixteen gentlemen, of whom thirteen were engineers. After six weeks on the isthmus, during which time the surveys and estimates of the engineers were completed, and the ceremony of breaking ground on the canal was performed in true theatrical style on the deck of a steamboat several miles from shore,* the whole party set sail for New York, arriving February 20, 1880.

From this date until April 1 (when he sailed for France) the time was spent in the United States. During these few weeks we hear of him now in New York, next in Washington, where he went to advocate his scheme before a Congressional committee, and then in San Francisco, in Chicago and in Boston—in all of which he was banqueted, and made speeches setting forth the grandeur of his enterprise and its importance to America. But the most important feature of this mission to the New World—to his stockholders at least—was the formation of what he termed his "American Committee," a body composed of representatives of the New York banking houses of Seligman & Co.; Drexel, Morgan & Co., and Winslow, Lanier & Co., under the presidency of Mr. R. W. Thompson, Secretary of the Navy, in the cabinet of President Hayes. This committee, for a consideration of 12,000,000 francs, allowed their names to be used as a pledge of the interest taken by the capitalists of the United States in the Panama scheme, and as guarantors (for so it was stated in France) of American neutrality.

The history of this journey and its results, recounted by de Lesseps in many lectures throughout France on his return, and duly proclaimed in the newspapers, whose uses no one understands better than the great Frenchman, prepared the way for his second appeal to the public for money, which was made in November, 1880. The amount asked for now was only 600,000 shares, or but three-fourths of the amount at first called for, it being a part of his policy to claim, as a result of his recent studies, that the work was less difficult and would require less money than was

* See Rodrigues, p. 66.

at first supposed, although in doing this he had to set aside the formal report of his own engineers.

The response this time (December 7, 8, 9, 1880) was very gratifying. Over 1,200,000 shares (\$120,000,000), or more than double the amount asked, were subscribed for by over 100,000 persons. As preferences were given to subscribers of 1879, to Suez stockholders, and to small subscribers up to five shares, all the rest had to content themselves with one-fourth of what they desired. And so at last the enterprise was set squarely upon its feet.

A company of engineers, agents and physicians was sent at once to Panama, to organize the works. But first of all it was necessary to provide for certain preliminary payments, some account of which may not be without interest.

1. First there was a charter payment of 750,000 francs to the Colombian Government, as provided in the act granting the concession.

2. A payment of 10,000,000 francs (\$2,000,000) to Wyse, Reclus & Co. for the transfer of their franchise, half in cash, and half in full paid stock, on which, as on the rest, five per cent. interest is paid from the time of its issue until the completion of the canal.

3. The reimbursement of all preliminary expenses, including those of Wyse, Reclus & Co., as well as those incurred by de Lesseps' journey to Panama, and including also the cost of the newspaper propaganda, banker's commissions, and all the expenses of the fiasco of 1879. Those who advanced the money for these purposes, and whose names have not been disclosed, are, in addition to this reimbursement, rewarded further by enrollment in the class of "Founders," who will, upon completion of the canal, be entitled to 15 per cent. of the net earnings, of which only 80 per cent. will go to the ordinary stockholders. Here again, the precedent of Suez has been closely followed, except that in the former case the founders receive only ten per cent. of the net earnings, instead of fifteen.

4. The immediate payment of 3,100,000 francs to the American Committee of Thompson, Seligman and others, to be followed by other payments, which will bring the total up to 12,000,000 francs, or \$2,400,000.

The sums paid on these various accounts up to June 30, 1881, as given by the official statement in the *Bulletin du Canal*, amount to 36,143,605 francs, or over \$7,000,000. From which it will be seen that, whatever be the ultimate fate of the enterprise to others, to certain parties it has already been an unqualified success.

Thus far of the company; we turn now to the canal itself.

The interoceanic canal at Panama, as proposed by de Lesseps, extends from Colon, or Aspinwall, on the Atlantic, to Panama, on the Pacific. It is to be a canal at sea level, de Lesseps having from the first declared that he would have nothing to do with any canal with locks. It must be, like Suez, a second Bosphorus, or nothing.* The depth of water is to be 9 metres (29.5 feet) and its least width 28 metres (92 feet). Its length will

* Since this was written, de Lesseps has very reluctantly consented to the use of locks in the summit, or Culebra section. But he insists stoutly that this is only as a temporary expedient to gain time, and does not involve any abandonment of the original scheme of a canal at sea level. See *Bulletin du Canal Interoceanique*, November 16, 1887, pages 1,833, 1,889.

be 74 kilometres, or nearly 46 miles. In a general way it follows, on the Atlantic side, the valleys of the Chagres and Obispo rivers, and on the Pacific side the valley of the Rio Grande being throughout its length very near the existing Panama Railway, which it crosses several times, and which it became necessary to buy almost at the outset. At Culebra, 33 miles from the Atlantic, and 13 miles from the Pacific, it crosses the dividing ridge in a narrow pass, whose elevation above the sea is 99 metres, or 325 feet. This makes the depth of the summit cutting, to the bottom of the canal, 350 feet, and at a few points the slopes reach up to elevations of more than 500 feet (169 metres).

At each end of the canal extensive harbor and dock works are designed, and on the Atlantic side, where it was necessary as a preliminary step, a great deal of work of this kind has been actually done. On the Pacific side a ship channel must be dredged for three or four miles out into the bay. And as the tides on this shore have a range of 20 feet, whilst on the Atlantic their range is less than two feet, a tide-lock, in spite of the protests of M. de Lesseps, will be a necessity, not only to prevent currents destructive to the works and embarrassing to navigation, but also to avoid the needless expense of lowering the whole canal to the depth that would be required by low tide in the Pacific. This great range of the Pacific tides also adds enormously to the difficulties of dredging, so that comparatively little has, so far, been done on this end of the work.

The quantity of earth and rock to be moved is, of course, very great, amounting to not less than 125,000,000 cubic metres, with a probability, amounting almost to certainty, that it will reach 140,000,000 cubic metres, or 182,000,000 cubic yards, which, if it were all earth, and under favorable circumstances, would require for its execution about six and a half years' work for ten thousand men.

But the magnitude and cost of the work are vastly enhanced by the peculiarly unfavorable circumstances under which it must be done. Amongst these we may mention, first of all, the climate, which is extremely enervating and destructive to human life. Malarial fevers of the most malignant type prevail at all seasons, whilst yellow fever, the deadliest of all, has found here such a congenial home that it has become a permanent resident. I cannot better describe this climate and its effects upon man than by quoting from the report of Mr. John Bigelow, made on April 1, 1886, after his return from the isthmus, whither he had gone with M. de Lesseps as a delegate of the New York Chamber of Commerce.

"For seven months of every year," he says, "it is liable to rain not only every day, but several times a day, and when it does rain at this season the water does not come down, as with us, in drops, but in sheets, so that to be out of doors when it rains means being as completely wetted as if thrown into the sea, and it means a suspension of work for at least two-thirds of the seven rainy months.

"To get cool from the effects of such a shower, so that the normal perspiration is checked, means for a Northern man, in nine cases out of ten, a fever in a few minutes and a funeral in a few hours. To this add the pestilential atmosphere engendered by a tropical sun falling upon the vast surface of vegetable matter continually moistened by rain, and you have a climate where it may, without exaggeration, be said that

'Life dies and death lives.' "

To mitigate, as far as may be, the effects of this climate, the Canal Company have spent large sums, amounting to several millions of dollars, in building hospitals and maintaining a medical service. But, after all that has been done, or can be done, the deadly and ever present climatic conditions remain, and must forever remain, untouched.

As to the actual mortality among the employés, no reliable statistics are available. The statement is made in a recent French publication that 70 per cent. of the Europeans who go to Panama die there; but the publications of the company are comparatively silent on this subject, and the statement can neither be proved nor disproved. A few facts, however, which leak out here and there tell a story of death which volumes could not make more impressive. Thus, soon after the organization of the company (June, 1881) we learn of the death from yellow fever of the General Secretary, M. Bionne, on his way home from Panama. Later the death of Mr. Gaston Blanchet, one of the principal engineers, is recorded, and again we are told of the death, within a few days, of the wife, son and daughter of M. Dingler, Director-General, while the report of de Lesseps, in July, 1886, mentions the death, during the year, of M. Boyer, another director of the works, as a loss "particularly grievous." Later still we have the statement, on good authority, though not in the official "Bulletin," that in five months of 1886 five out of six chiefs of division were stricken from the rolls by death, and that out of thirty robust Italians who landed at Colon October 1, 1885, to act as foremen, twenty-five were dead within the month.* Ghastly stories are also told of robberies of the dead by their late companions, of half-buried bodies uncovered by the tides, and of still others buried mountain deep by rolling them down the dumps and covering them with earth from the excavations—stories which it is not necessary to believe to feel sure that the whole work is a hand-to-hand struggle with death in some of its ugliest forms.

But a still more serious obstacle to the successful prosecution of the work is presented, under various forms, by the water, always the arch-enemy of the engineer.

In a canal at sea level, such as this, the whole prism of the canal itself, and in many cases much more, must be excavated under water. If the material be such as will admit of dredging, it can be removed in this way, as is now being done in the few miles next to Colon. But if it be rock, this becomes impracticable, and recourse must be had to other methods, either of which will very greatly increase the cost as well as the time which will be required.

Furthermore, a canal at sea-level is, of course, at all points below the adjoining country, so that all the excavated material, unless carried out to sea, as is done with part of it, must be deposited above the level of the canal itself. This is followed by a constant tendency of what is thus deposited to flow back into the excavations, and in a country with a rainfall of from eleven to fourteen feet a year, with single showers of twelve inches a day, this tendency is almost irresistible. Already no little trouble of this kind has been encountered, and the statement is made on the most credible authority, that in the marshes near Colon earth

*New York Tribune, August 26, 1886. Letters from Panama.

dumped on the banks not only tends to run back into the canal, but causes a heaving up of the bottom, so that where, on quitting work at night, there may be a depth of water of eight or ten feet, there will sometimes be next morning but two or three feet.

By far the most serious form of this ever-present water trouble, however, is that presented by the rivers through whose valleys the canal is compelled to pass. Being at sea level, the bed of the canal must be below the beds of all the streams. From this it follows that unless these streams can be successfully diverted into new channels, the construction of the canal will be the well-nigh impossible task of lowering their beds in some cases two and three hundred feet, with the water still in them, and it follows still further that even if this were practicable the canal would, when done, have to take the whole drainage of every water-shed through which it runs. The Chagres River, however, to say nothing of the rest, is at its lowest a stream of from 150 to 200 feet in width, which is from 50 to 100 per cent. greater than the canal, while in freshets it has a width of 1,300 feet, with a depth of from 40 to 50 feet, and is a wild torrent, which, if turned into the canal, would sweep it and all it contained to certain destruction. Unless, therefore, the Chagres River can be successfully diverted the construction of the canal is impossible, and even if it could be made it could not be maintained. Even if, by a fiat of Almighty power, it were to be cut precisely as it is designed, the first freshet would destroy it as a navigable channel.

To effect the control of this stream, the plans of de Lesseps embrace a series of lateral channels on both sides of the canal, and a gigantic dam to be built at Gamboa, about twenty-seven miles from Colon, whereby the flood waters of the Chagres are to be impounded and then let slowly off by sluice ways. This dam was at first to be built of masonry, and to be 160 feet in height. Since then it has been found that there is no bed rock on which such a structure could rest, and no stone suitable for building it. The original plan has, therefore, been changed, and it is now designed to make it of earth and loose rock, taken from the great summit cut of Empire and Culebra.

But the possibility of successfully placing such a structure across such a stream, and its stability when done, are both matters of extreme doubt, with the probabilities decidedly in the negative. At best it is an experiment, whose failure means the failure of the whole enterprise.

And yet, strangely enough, although everything turns upon the completion and successful working of this great dam, I cannot find that anything at all has yet been done toward its actual construction. The work, so far done, aside from a somewhat extravagant preparation of plant and buildings, consists almost wholly in dredging on the Atlantic side between Colon and the first crossing of the Chagres, and in excavating the ridges and high grounds of the interior, where the trouble from the water is the least, while the difficult and problematic work has been left almost wholly untouched.

The quantity of material actually moved up to April 1, 1886, as given in a report of M. Jules C. Roux to the Marseilles Chamber of Commerce, published in the *Bulletin du Canal* for June 1, 1886, is 21,594,318 cubic metres, of which 3,183,000 cubic metres were done in the months of

January, February and March, 1886. Taking the total quantity to be moved at 125,000,000 cubic metres, which is a very moderate estimate, the quantity moved up to April 1, 1886, is only $17\frac{3}{10}$ per cent. of the whole. But when we take into account the much greater difficulty of what remains, and the probability that the total will reach 140,000,000 or 150,000,000 cubic metres, it is within the truth to say that, at the date mentioned, not over 10 per cent. of the work had been actually done.

The amount expended; up to January 1, 1886, as given by the same report—a more than friendly one—is 448,500,765 francs, or \$89,700,153. Deducting from this the amount spent in [purchasing the Panama Railway, to wit: 93,878,225 francs, or \$18,775,645. we have as the sum chargeable to the canal, 354,622,540 francs, or \$70,924,508. Of course, a considerable part of this has been used for expenses of organization, and for buildings and plant which will be available for future work. Allowing for these items, we find the probable cost of the work remaining January 1, 1886, to be 2,676,309,713 francs, or \$535,262,000, which, added to the amount already spent, will bring the actual cash cost of the canal and railroad up to \$625,000,000.*

Up to the time of this report (April, 1886) the company had raised money by issuing about \$140 in interest-bearing securities for every \$100 raised in actual money. Since then, however (August 3, 1886), bonds calling for an ultimate payment of 1,000 francs have been issued for 400 francs cash, or at the rate of \$250 in securities for \$100 in money. It will, therefore, be giving the company the benefit of the doubt if we put the final average of the securities at \$175 for each \$100. This will bring the capital account ultimately up to \$1,093,754,000, upon which the interest charge will not be less than \$40,000,000 per year.

All this is upon the supposition that the problem of controlling the rivers is successfully solved, and that the supplies of money continue to the end. But as the successful solution of the Chagres problem is a matter of the gravest doubt, and as the most sanguine estimates of the net revenues of the canal do not bring them up to one-half of the \$40,000,000

* The figures are as follows:

The total expenditures from January 1, 1881, to December 31, 1885, as given by M. Roux (see supplement to <i>Bulletin</i> of June 1, 1886, page 25) amount to.....		448,500,765.49 francs.
From which are to be deducted for expenses incurred once for all, and applicable to future work, the following items:		
1. Expenses of organization.....	25,393,605.88 francs.	
2. Real estate on the isthmus.....	11,609,122.91 "	
3. Office and furniture in Paris.....	1,973,612.35 "	
4. Cost of Panama Railway.....	93,878,225.33 "	
5. Two-thirds cost of tools, etc... ..	18,278,451.00 "	
Total deductions.....		151,133,017.65 francs.
Leaving as the real cost of the work done up to January 1, 1886, say, one-tenth of the whole.....		297,367,745.84 "
This, multiplied by ten, gives us the cost of the whole work..		2,973,677,458.40 "
To which should be added the cost of organization, real estate, etc., as given above.		151,133,017.65 "
Which gives us the whole cost of the canal and railroad.....		3,125,010,476.05 francs, or \$625,002,095 in gold.

These figures (made January, 1887) are more than confirmed by a recent report to the Colombian government by Señor Armero, who, after a careful inspection of the whole situation on the ground, estimated the expenditures of the company up to September 1, 1887, at 818,032,900 francs, and the cost of the work yet to be done at 3,012,495,400 francs, making the total cost 3 830,528,300 francs, or \$766,105,660 in gold.

See *Engineering News*, New York, November 18, 1887, page 369.

required for interest, it would seem that the present undertaking can have no other ending than collapse and bankruptcy. Probably it will last during the lifetime of de Lesseps, for the faith of his countrymen in the hero of Suez appears to have no limit; but it does not seem possible that it can survive his death. As he is now 82 years of age, the ordinary tables of mortality would seem to make it almost certain that within the next five years, and possibly much sooner, the end will come, both to the company and to the man.

But the hope of securing interoceanic ship communication will not then be given up. The world has too great an interest in the solution of this problem to abandon it until every possibility has been exhausted. It may be that, upon the ruins of present Panama Company, there will arise another company, which will carry this work in some form to completion. The probabilities of this, however, will depend not only upon the prospects at Panama, but upon the advantages offered by the other interoceanic routes.

Let us, then, consider next what prospects for a solution of this problem are presented by

THE TEHUANTEPEC ROUTE.

More than 1,300 miles to the west of Panama a very notable narrowing of the American isthmus is found at Tehuantepec, in the southern limits of Mexico, and just west of the peninsula of Yucatan. This contraction of the isthmus long ago suggested it as a possible route for a canal, and several surveys have been made with this end in view. These developed the facts that the breadth of the isthmus at this point is 144 miles, or three times that of Panama, and that the height of the summit is nearly 700 feet, or double that of Panama, so that as a route for a canal it is highly unfavorable. As a means of interoceanic ship transfer, it would, indeed, have been wholly abandoned, had it not been for the efforts, during the last eight years, of the gifted engineer Capt. James B. Eads, who has brought it forward, however, not as a route for a ship canal, but for a ship railway.*

More than thirty years ago, during the discussion preceding the construction of the Panama Railway, a scheme for a ship railway was proposed by Dr. W. F. Channing, of Providence, R. I., and in 1865 he took out patents for the details of his plan.

Still later, in 1872, the Government of Honduras adopted a scheme for a ship railway through its own territory, and sought a loan of money therefor in England, the plans going out with the endorsement of Mr. Jas. Brunlees, now a past president of the Institution of Civil Engineers. But the application for money met with no response, and the project was dropped.

Shortly after the Paris Congress of 1879 had reported in favor of a canal at Panama, Capt. Eads, who had just completed the jetties at the mouth of the Mississippi, took up the problem of inter-oceanic ship transfer, and reached the conclusion that the solution was a ship railway. When, therefore, de Lesseps appeared in Washington before a Congressional Committee; in March, 1880, to convert the Americans to his canal scheme,

* Since this was written Capt. Eads has died (March 8, 1887), deeply regretted by his associates, and to the great loss of the engineering profession.

Capt. Eads was there also to challenge his conclusions and present his own scheme for transferring ships by rail. At that time he had not selected any particular location for his road, but in his answers to the Committee seemed to prefer Panama or Chiriqui, a short distance to the west of Panama. During the following summer he also urged his scheme before the merchants of San Francisco, as De Lesseps had also done a few months before. But he did not yet indicate any choice of route.

During the next year, however, to wit: May 28, 1881, he succeeded in obtaining from Mexico a very liberal franchise for the construction of a ship-railway across the isthmus of Tehuantepec, and from thenceforth his scheme has had a local habitation and a name. Ever since then he has been working with an untiring energy, which de Lesseps himself could not surpass, explaining his plans, and endeavoring with a rare skill to enlist public sentiment and the public money to aid him in realizing them.

In a general way these plans, as now evolved, consist in a railway with three tracks of ordinary gauge, laid side by side, so that the outer rails shall be 29 feet apart. The rails to be of steel weighing from 100 to 120 pounds per lineal yard, or nearly double the weight of those in ordinary use, laid upon long steel ties extending under the whole of the six rails of the railway. The road bed to be from 45 to 50 feet wide, and constructed in the most substantial manner possible. The road is to be located so as to have no curve of less radius than 20 miles. At points where a more rapid change of direction is required, five floating turn-tables of novel design will be introduced. The maximum gradient is intended to be one per cent. or 53 feet per mile.

In the harbor at each end of the railway is to be constructed an immense floating dock, upon which will rest the carriage that is to receive the ship. The dock and carriage being submerged, the ship is to be brought immediately over it and made fast. A very ingenious arrangement of hydraulic rams is then provided by which there will be placed under the ship the blocking by which it is to be held in position on the carriage. The water will then be pumped out of the dock, and the whole, dock carriage and vessel, raised up until the rails of the dock are on a level with those of the railway. Powerful locomotives are then to be attached to the carriage which will be drawn ashore and the ship started on its way to the other ocean, where, by a reverse process it will be let down again into its proper element, and sped rejoicing on its way.

In considering the practicability of this plan, so admirably simple in its outlines, the first thing that strikes the mind is the impossibility of making any appeal to experience, as nothing comparable to it has ever yet in the whole history of the world been actually done. It is true that small boats up to 200 or 300 tons weight have been taken out of the water and transported successfully short distances over land. But nothing has ever been done which affords any precedent for the landing and transportation of a vessel of 7,000 tons, as is proposed by Capt. Eads.

Of course this absence of experience is not in itself conclusive. Things without precedent, and once deemed impossible, are done every day, and the plans of Captain Eads for landing and transporting ships, novel

as they are, may be entirely sound. But with this, as with all novelties, the burden of proof certainly lies with him who affirms, and until the thing has been actually done, and its practicability established beyond question, one may well be pardoned for doubting. For as we study the problem in details, the enormous difficulties which it presents grow upon us.

For example, the docking of even an empty vessel is well known to be a work requiring the greatest possible care and attended with no little risk, so much so that in the words of a prominent engineer who is an expert in such matters, Mr. Thomas F. Rowland, Vice-President of the American Society of Civil Engineers, "few vessels are dry-docked without sustaining more or less permanent injury."* But to dock a vessel which is not empty, but with her cargo all on board, is like a capital operation in surgery, something through which one may pass and yet live, but to which one never subjects himself except in the direst extremity.

Yet this is the ordeal to which Capt. Eads proposes to subject every ship that crosses the isthmus.

But, again, let us suppose the vessel to have gone thus far in safety; let us say that she has been duly placed in position on the carriage, and that the carriage has been raised to its place at the end of the railroad track ready to be hauled ashore, he will be a bold seaman who will contemplate without dire apprehension the next step, that, namely, of passing from the floating dock to the land. For any one who has ever watched a train pass off from a railway ferry, and noted the surging of the boat under the constantly changing conditions of equilibrium, as the load moves off, will see at once that to land a vessel safely from a floating pontoon must be an extremely difficult and delicate operation. It is, in fact, something which has never yet been done with any vessel whether large or small, and as to the practicability of which with large ships I must confess to being a profound skeptic.

When we contemplate the movement of the vessel over the land, we find still other difficulties hardly less serious. Thus, the carriage on which Captain Eads places his vessel rests, as shown by his published plans, on 360 wheels, and will weigh, for a 7,000 ton ship, not less than 1,000 tons. This, added to the weight of the ship, gives a total load of 8,000 tons. If distributed equally over the 360 wheels, this gives a weight per wheel of something over 22 tons, or more than double the weight on the drivers of the heaviest locomotives. But a moment's study of the conditions of the loading will show that the weights per wheel cannot be equal, but must be very unequal, so that on some of the wheels there will be loads three or four times the mean loading already mentioned. That is to say, there will be on some of them loads of 60 or 80 tons which no wheels and no track of which we now have any knowledge could bear without destruction.†

* See Sullivan on Interoceanic Communication, page 203.

† It is worth mentioning that the plans of Captain Eads, as set forth in the *North American Review* for March, 1881, and upon which the favorable opinions of engineers and others, contained in his pamphlet of 1882, were obtained, differed in some respects very materially from those which he has published since. Thus, at that time it was his intention to have twelve rails, instead of six, and there were to be 1,500 wheels under his carriage, instead of 360, which he proposes now. This, of course, would greatly reduce the weight per wheel, though it would double the cost of the track, and much more than double the cost of the carriage.

Difficulties of the same sort are presented in the stopping and starting of the carriage, in getting it safely over the numerous hydraulic turntables, in hauling it up to the summit, and still more, in controlling it as it goes down, though, singularly enough, the published drawings of the carriage do not show any brakes whatever. In fact, the whole problem is beset from end to end with difficulties of the greatest magnitude, and with not a single ray of light from actual experience to guide us.

It is hardly wonderful, therefore, that in the words of Admiral Ammen "not a single ship-owner in our country has intimated his willingness to trust his ship on this railway, nor a single insurance company its willingness to take risks, nor a single builder of ships in this country, his belief that ships could thus be safely transported."

But, even if every mechanical difficulty were to be fully solved, there is one other consideration which ought, I think, to be conclusive, and that is the fact that the cost of transportation on a ship railway must of necessity be far greater than by canal.

To say nothing of the great cost of maintaining a three-track railway in the perfect order needed for the transportation of ships, or the cost of maintaining and operating the enormous docks and turn-tables, to move a ship over a railway requires an expenditure of energy, and therefore, of money, vastly greater than is required to transport it by a canal.

In a canal the work of lifting the ship, if lifting be required, is all done in the locks by the action of the water in seeking its level, whilst the work of translation through the water, in which the friction is a minimum, will, in most cases, be done by the ship's own power. On the railway, upon the other hand, the company must furnish all the power, not only to move the ship against a friction vastly greater than that of the water, but also to lift it, and in the case of Tehuantepec, to lift it over a summit not less than six times as high as would be required by a canal. So that, if the railway were in successful operation, the cost of doing its work would be so great that, if a canal were also to be built, it is difficult to see how a single ship could afford thereafter to go by rail.

This brings us to the last of the three projects which we were to consider, viz.: that for a

CANAL VIA LAKE NICARAGUA.

Almost from the discovery of this lake, a sheet of water whose greatest length is about one hundred miles, it has been proposed to utilize it as part of a canal to connect the two oceans. For this purpose quite a series of surveys, both for governments and for private corporations, have been made, so that next to Panama it is the most thoroughly known of all the interoceanic lines.

According to the latest of these surveys, made by Mr. Menocal, Civil Engineer, U. S. Navy, in the winter of 1885, the proposed canal begins at San Juan Del Norte, or Greytown, on the Atlantic, and extends via the San Juan River and Lake Nicaragua to Brito, on the Pacific, a distance of 170 miles, the general direction being nearly east and west. Of this distance it is proposed to utilize the lake and the San Juan and San Francisco rivers (the two latter being converted by dams into a deep slack-water pool, which shall be virtually an extension of the lake) for a total distance of $129\frac{1}{2}$ miles, or more than 76 per cent. of the whole 170

miles. The remaining $40\frac{1}{2}$ miles will be a canal, in which it is proposed by Mr. Menocal to put seven locks, three on the Atlantic side and four on the Pacific side. These locks are to be 650 feet long and 65 feet wide, or large enough to take in the largest ships now afloat, the Great Eastern alone excepted. The next largest, the City of Rome, whose length over all is 600 feet, with 52 feet beam and a displacement of 13,500 tons, will be easily accommodated. The least depth of water will be 29 feet, and its greatest elevation will be the level of the lake, or 110 feet above mean tide, which is about one-sixth of the summit level at Tehuantepec. Harbors will have to be constructed at either end, the present ones being wholly insufficient. The cost of these is estimated at \$3,400,000.

The cost of the whole canal, including the harbors, and an allowance of 25 per cent. for contingencies, is put by Mr. Menocal at \$64,000,000. Doubling the allowance for contingencies, and making it 50 per cent. instead of 25, the cost will amount to \$76,800,000, which it will be noted is but \$6,000,000 more than had been spent at Panama on January 1, 1886, for not over one-tenth of the whole work. Captain Eads' estimate of the cost of his ship railway is \$75,000,000.

In weighing the comparative merits of the scheme thus outlined, the first thing that strikes the mind is that there is in it nothing that is experimental or doubtful. It presents no such mechanical problems as are involved in the successful working of a ship railway, nor such as are involved in the control of the Chagres River. Lake Nicaragua, which has an area of 2,600 square miles, is a reservoir already built, by which the flow of the water is equalized and the violence of freshets effectually controlled. In fact, the total rise and fall of that part of the San Juan River which it is proposed to utilize for the canal does not exceed 6 or 7 feet, as compared with 50 feet in the Chagres. Moreover, the fact that for the most part the canal is to be above the sea level, removes the larger part of the difficulties, and simplifies the whole construction. It is in fact but a repetition, on a larger scale, of what has been done elsewhere over and over again.

As compared with Tehuantepec, it has, moreover, the great advantage that it will accommodate the largest ships. Capt. Eads does not propose to transport any ship greater than 7,000 tons, which would exclude all the larger vessels. It would, for example, exclude nearly all the New York and Liverpool steamers, which range from 9,000 to 13,000 tons displacement, as well as the larger Pacific mail steamers, such as the Tokio and City of Peking, which are 9,000 tons each. But, if we are to spend \$75,000,000, or any large sum, to transport vessels, we ought certainly to provide for the transportation of vessels such as these.

For these reasons, the verdict of the United States Interoceanic Canal Commission, in 1876, in favor of the Nicaragua route, already referred to, seems to be the verdict of sound judgment and common sense. And yet, whenever, during the last few years, this enterprise has appeared in Congress as an applicant for national recognition and aid, the friends of Tehuantepec and of Panama, including de Lesseps' "American Committee," though foes at all other times, have always worked together and secured its defeat. Notwithstanding the immense importance of the subject to the commerce of this country, and the world, this

scheme has not yet been able to secure from the representatives of the people, the serious and respectful attention which its undoubted merits will yet command.

CONCLUSIONS.

Looking back, by way of review, over what has gone before, we are, I think, amply justified in stating the following conclusions :

1. That the Tehuantepec ship railway scheme is essentially of an experimental character, the successful working of which is highly problematic.

2. That, even if successful as a mechanical problem, the transportation of ships by rail will cost more than by any other method which has yet been proposed.

3. The railway proposed by Capt. Eads does not provide for transporting, at any cost, the larger class of vessels.

4. That the possibility of maintaining a sea level canal at Panama turns upon the possibility of controlling the floods of the Chagres River.

5. That as the feasibility of such control has not yet been demonstrated, the success of the Panama Canal, as an engineering scheme, is still doubtful.

6. That even if practicable, the cost of the canal at Panama will be so great that it cannot be other than a financial failure.

7. That a ship canal by way of Lake Nicaragua involves in its engineering features nothing experimental or doubtful, and can be built for a sum not greater than is required for the ship railway, and for four or five hundred millions less than will be needed for the canal at Panama.

8. The canal at Nicaragua is therefore the best solution of the problem of interoceanic ship transfer, and is the one upon which the energies of the American people should be concentrated.

VULCANIZATION OF WOOD PULP—A NEW METHOD OF TREATING FIBROUS MATERIAL.

BY MARK L. DEERING, M. E., MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read November 22, 1887.]

In a paper read by me before this Club some time ago, entitled "Wood Pulp and Some of Its Peculiarities," which related to the manufacture of seamless wood pulp barrels, I hinted at some experiments I was then engaged upon tending toward the vulcanization of wood fibre, and which I have kept up until I accomplished the desired end (the missing link mentioned in that paper).

The results of those experiments were so remarkable that no one could be more astonished by them than myself. I began, of course, with considerable knowledge of the material and all its treatments, being familiar not only with my own processes from years of practical laboratory and factory work, but also with that in general use at the various manufactories of indurated fibre throughout the country.

One trouble with the indurated fibre ware, so called, is that it takes

about 6 days to complete an article, such as a pail or wash-basin, and when completed it lacks the requisite strength, being strong only in the glaze or shell of exceeding thinness on the outside of the vessel, the inside being pulpy, and when the glaze wears off, this filling is moistened and then the inside will swell, which of course destroys the utility of the article. Then the process is too costly, a large article like a barrel costing upward of \$3.

My object was to obtain three distinct results:

First. A material impervious to moisture of any kind, all through its fibre, resisting not only water and oil but also alkali and acids to a marked degree.

Second. A solid and strong article with a high tensile strain.

Third. To avoid the expense and waste of time required to complete an article by reducing the processes which it must pass through and expediting its completion as much as possible.

In the first place I take spruce pulp (in sheets) as it comes from the mills, and beat it into pulp. Then I take pitch and treat it in an electric bath, which changes its nature entirely, then the pitch and pulp are mixed together in proportion of 1 to 20 and put in another beating engine, the water contained therein being also heavily charged with electricity. This product is then pressed into pails, wash-basins, etc., in molds and in the usual manner; then the vulcanizing is done with a temperature of from 325° to 350° Fahr., or to a point sufficiently high to melt the mass. This gives me a product which maintains a uniform strength, color and density throughout, which averages tensile strength of 9,000 per square inch of section; a result so remarkable as to be almost incredible. It is capable of taking a high polish resembling gutta percha or hard rubber in a marked degree.

It is a good non-conductor of electricity (resisting 4,000,000 ohms) and being almost as good as hard rubber for such purposes, and by a slight variation in the proportions and temperature of vulcanizing it can be made exceedingly flexible and even pliable; but the strangest property of this material is found in its readiness to join with other pieces precisely as two pieces of India rubber are joined together.

By this process I can make articles in the forenoon from the raw pulp and in the afternoon it will be completed and ready for shipment; in fact, a barrel can be made ready to be filled with petroleum (or its products) in ten to fifteen minutes and at a cost of 2 cts. per lb.

I present to you some samples of this vulcanized fibre as worked into vessels, and am sure that any tests made with them will more than vindicate my confidence in this substance and justify my claim of having obtained a product by my process at once unique and possessing many remarkable qualities.

DISCUSSION.

After reading his paper, Mr. Deering exhibited a number of articles made from vulcanized wood pulp. He first described the process of manufacture of what is called "indurated fibre." He then exhibited a wash basin made of vulcanized wood pulp. Holding a wash basin in his hand, he stated that the time required to convert this wash basin from a

pulpy state to a vulcanized material like that exhibited does not exceed twenty minutes. Its color when taken out of the vulcanizing mold is black; the brown color is obtained by staining.

Mr. John Walker: I think this material can be molded into any shape and take the place of lignum vitæ for boxes and bearings in machinery. We have experimented with it in that direction. We have water pails made of it at our works. Mr. Walker then enumerated articles that could be made from wood pulp.

Mr. A. C. Getchell: As long ago as 1847 I saw boxes made from paper pulp.

Mr. Deering: The object in using the electric current is to dissolve the pitch and make it mix with the water and pulp, in fact, to form a new material. There are some tricks connected with this invention that I cannot tell; but the result I give you. There is another concern now experimenting with pitch and tar, but they do not use electricity. After the pitch or tar is brought to a certain state it will be held in suspense in the water and mix intimately with the pulp. Articles are first pressed in a roughing mold, perforated to let off the water, and are then put into a smooth mold the exact shape of the article I want to make and vulcanized in this mold. The piece I now hold in my hand was at one time in two separate pieces. They were vulcanized at a degree below 500 degrees Fahr. They were then put back in the mold, pressed and vulcanized again at a temperature of about 350 degrees Fahr. The piece had holes drilled and bolts in it like a piece of hard rubber.

I do not think there was over 300 pounds to the square inch. It depends to a great degree upon the pressure of the steam that does the vulcanizing.

Mr. Rawson: I have bought articles like this (referring to indurated fibre ware) from the Cleveland Paper Co. After using such articles a while they began to swell and blister.

Mr. Deering: When the glaze is worn off the indurated fibre, the water gets into the soft pulp in the inside, and causes it to swell. My object was to have a material that would be solid all the way through, so that if the surface should be worn, water or other liquids could not penetrate it.

The material in that basin is worth two cents per pound. Deoxidized linseed oil is the principal ingredient used in the indurated fibre. It is worth eight cents to nine cents per pound. The articles are dipped in it three to four times, and baked each time at a temperature of about 280 degrees Fahr., taking about six days to complete an article. Some of the articles can be bent after they are taken out, and they will not break. I have made flat pieces that could be bent like a piece of wood weeks after they were made. The pulp is the most expensive ingredient I use. I can use any kind of pulp, either straw or wood.

I have tested pieces like this. I have found that some would have a tensile strength of 9,000 pounds to the square inch, and the lowest I found was 5,000 pounds.

I had the Western Union test it as an insulator, and they found it about as good as rubber. This substance will not burn. It may ignite and carbonize while in contact with fire. When withdrawn from the



TABLE SHOWING MOMENTS OF RESISTANCE OF PLATE GIRDERS, AS CALCULATED BY DIFFERENT FORMULAS.

p = Thickness of plates in one flange.
 a = Depth of vertical leg of flange angle.
 $h_1 = h_2 = c$.
 h_1 = Distance out to out of flange angles.
 h_2 = " " centre to centre of gravity of flanges.
 h_3 = " " out to out of flanges.
 W = Area of web.
 F = Total flange area.
 A = Area of angles.

ELEMENTS OF SECTION.

MOMENTS OF RESISTANCE IN INCH LBS.

No.	h			Size of web.	Size of each flange angle.	Size of plates in one flange.	1. Calculated from moment of inertia.	2.		3.		4.		5.		6.	
	h	h_1	h_2					$\left(F + \frac{W}{6}\right)h - A(a + 2p)$	P. ct. err'r.	$\left(F + \frac{W}{6}\right)h_2 - 2Fc$	P. ct. err'r.	$\left(0.95F + \frac{W}{6}\right)h - W$	P. ct. err'r.	$\left(F + \frac{W}{6}\right)h_1$	P. ct. err'r.	$F \times h_1$	P. ct. err'r.
	In.			In.	Lbs.	In.		Moment.		Moment.		Moment.		Moment.		Moment.	
1....	12.52	12.00		$\frac{1}{8} \times 12$	$3\frac{3}{4} \times 2\frac{1}{2}$	$\frac{1}{4} \times 4.9$		35.00		35.43	1.23	34.08	3.6	37.27	5.25	37.29	6.5
2....	11.225	12.625		$\frac{1}{8} \times 12$	$3\frac{3}{4} \times 2\frac{1}{2}$	$\frac{1}{4} \times 4.9$		35.80		36.09	0.52	35.25	1.0	38.70	5.22	60.90	9.2
3....	11.704	13.25		$\frac{1}{8} \times 12$	$3\frac{3}{4} \times 2\frac{1}{2}$	$\frac{1}{4} \times 4.9$		76.84		76.75	0.11	76.24	0.8	80.02	4.15	85.38	11.2
4....	16.28	18.00		$\frac{1}{8} \times 18 \times 3$	5×5.9	$\frac{1}{4} \times 6$		69.96		69.97	0.014	68.44	2.20	71.65	2.42	72.92	4.2
5....	17.17	18.75		$\frac{1}{8} \times 18$	5×5.9	$\frac{1}{4} \times 6$		114.47		114.67	0.087	113.74	0.6	116.63	1.89	121.95	6.5
6....	17.756	19.50		$\frac{1}{8} \times 18$	5×5.9	$\frac{1}{4} \times 6$		159.98		159.16	0.075	159.04	0.15	161.43	1.34	172.79	8.5
7....	18.08	30.00		$\frac{1}{8} \times 24$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		189.44		188.90	0.29	189.10	0.18	191.25	0.94	207.51	9.5
8....	22.44	34.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		134.71		134.58	0.096	133.98	0.51	136.04	0.97	139.80	3.8
9....	22.30	34.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		170.15		171.12	0.57	168.43	1.00	175.71	3.22	177.79	4.5
10....	23.22	34.75		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		211.65		211.84	0.09	212.16	0.24	213.10	0.98	223.02	5.4
11....	23.77	35.50		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		288.98		289.11	0.05	290.40	0.50	289.95	0.34	308.52	6.8
12....	24.10	33.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		310.81		310.62	0.06	314.58	0.52	314.24	0.12	366.89	7.7
13....	23.85	30.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		379.06		379.68	0.16	380.12	0.28	385.42	1.68	410.69	8.4
14....	30.24	30.00		$\frac{1}{8} \times 30 \times 3$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		181.12		181.33	0.11	180.66	0.27	179.43	0.94	186.00	2.6
15....	30.30	30.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		237.01		238.31	0.57	235.35	0.69	239.02	0.93	284.40	3.25
16....	30.22	30.75		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		379.06		379.68	0.16	380.12	0.28	385.42	1.68	410.69	8.4
17....	30.29	31.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		310.81		311.35	0.16	312.28	0.47	307.67	1.02	324.70	4.50
18....	30.27	31.50		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		375.06		376.36	0.16	378.05	0.63	371.81	1.03	386.64	5.30
19....	30.00	32.00		$\frac{1}{8} \times 30$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		440.67		441.37	0.16	443.99	0.74	435.93	1.07	467.08	6.0
20....	34.41	36.00		$\frac{1}{8} \times 36$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		232.01		231.84	0.07	231.24	0.35	232.07	0.28	259.08	1.76
21....	34.30	36.00		$\frac{1}{8} \times 36$	$3 \times 4 \times 11.2$	$\frac{1}{4} \times 9$		287.70		288.26	0.54	286.57	0.40	286.47	0.33	394.81	2.50
22....	35.23	36.75		$\frac{1}{8} \times 36$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		354.38		349.61	1.23	350.39	1.12	342.40	3.38	360.30	1.7
23....	35.42	37.00		$\frac{1}{8} \times 36$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		387.78		388.86	0.86	390.17	0.63	380.87	1.53	402.19	3.7
24....	35.77	37.50		$\frac{1}{8} \times 36$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		465.86		467.37	0.32	469.60	0.81	457.81	1.73	486.65	3.8
25....	36.09	38.00		$\frac{1}{8} \times 36$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		544.11		545.88	0.33	549.11	0.92	538.76	1.72	572.31	5.3
26....	36.08	38.00		$\frac{1}{8} \times 36$	$3 \times 4 \times 8.3$	$\frac{1}{4} \times 9$		699.08		699.66	0.08	704.49	0.77	687.02	1.73	734.96	5.1
27....	40.44	42.00		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		286.15		286.10	0.03	285.51	0.23	277.46	0.92	289.85	1.3
28....	41.22	42.75		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		439.90		439.11	0.29	435.13	0.53	412.12	2.55	434.50	2.8
29....	41.77	43.50		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		550.90		552.12	0.40	554.83	0.88	548.79	1.25	581.33	3.8
30....	42.09	44.00		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		651.42		654.13	0.42	657.99	1.00	638.59	2.92	680.49	4.5
31....	42.18	44.00		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		580.04		573.38	1.14	575.97	0.70	562.3	3.04	592.03	2.1
32....	42.18	44.00		$\frac{1}{8} \times 42$	$3 \times 5 \times 10.2$	$\frac{1}{4} \times 12$		911.31		914.82	0.31	917.83	0.70	901.37	1.11	955.83	4.8
33....	45.00	45.00		$\frac{1}{8} \times 45$	6×16.0	$\frac{1}{4} \times 14$		485.31		485.79	0.10	483.98	0.24	479.33	1.12	494.63	1.90
34....	46.01	48.00		$\frac{1}{8} \times 48$	6×16.0	$\frac{1}{4} \times 14$		518.07		518.40	0.37	516.50	0.39	512.72	0.28	526.73	2.25
35....	44.5	48.00		$\frac{1}{8} \times 48$	6×24.2	$\frac{1}{4} \times 14$		743.18		753.84	1.42	739.32	0.52	788.11	5.87	779.64	4.90
36....	48.85	48.75		$\frac{1}{8} \times 48$	6×16.0	$\frac{1}{4} \times 14$		788.13		787.20	1.12	789.33	0.16	782.16	0.77	812.85	3.5
37....	48.41	49.50		$\frac{1}{8} \times 48$	6×20.2	$\frac{1}{4} \times 14$		1032.93		1032.00	0.93	1035.88	0.35	1021.56	1.08	1072.14	3.90
38....	47.54	51.00		$\frac{1}{8} \times 48$	6×20.2	$\frac{1}{4} \times 14$		1298.92		1301.04	0.16	1301.97	0.25	1296.07	0.22	1360.31	4.7
39....	47.456	61.00		$\frac{1}{8} \times 48$	6×24.2	$\frac{1}{4} \times 14$		1712.74		1718.28	0.32	1712.75	0.00	1745.71	3.81	1838.00	6.80
40....	50.01	60.00		$\frac{1}{8} \times 60$	6×16.0	$\frac{1}{4} \times 14$		726.80		725.10	0.24	725.29	0.21	715.95	1.61	738.18	1.60
41....	50.550	60.00		$\frac{1}{8} \times 60$	6×24.2	$\frac{1}{4} \times 14$		969.45		971.58	0.84	957.66	0.67	966.39	3.43	996.94	3.5
42....	50.95	61.00		$\frac{1}{8} \times 60$	6×16.0	$\frac{1}{4} \times 14$		1134.93		1135.50	0.50	1138.92	0.44	1129.81	1.78	1164.40	2.60
43....	50.708	62.00		$\frac{1}{8} \times 60$	6×24.2	$\frac{1}{4} \times 14$		1729.67		1732.54	0.56	1731.50	0.09	1794.39	3.29	1857.81	4.8
44....	50.88	64.00		$\frac{1}{8} \times 60$	6×29.2	$\frac{1}{4} \times 14$		2766.76		2781.00	0.51	2773.46	0.34	2797.14	1.10	2947.72	6.5
45....	50.218	65.00		$\frac{1}{8} \times 60$	6×24.2	$\frac{1}{4} \times 14$		4398.20		4390.92	0.17	4398.58	0.01	4393.14	0.12	4804.64	9.30
46....	50.218	65.00		$\frac{1}{8} \times 60$	6×24.2	$\frac{1}{4} \times 14$		1373.13		1384.39	0.73	1367.80	0.42	1390.17	1.33	1362.87	3.80
47....	70.709	74.00		$\frac{1}{8} \times 72$	6×24.2	$\frac{1}{4} \times 14$		2356.70		2356.70	0.39	2357.77	0.04	2354.44	3.94	2616.92	1.8
48....	72.122	76.00		$\frac{1}{8} \times 72$	6×20.2	$\frac{1}{4} \times 14$		3322.10		3340.84	0.50	3343.73	0.61	3305.37	0.58	3391.18	1.5
49....	72.183	78.00		$\frac{1}{8} \times 72$	6×20.2	$\frac{1}{4} \times 14$		4294.22		4309.30	0.35	4317.94	0.55	4265.07	0.67	4575.59	6.53
50....	75.27	82.00		$\frac{1}{8} \times 72$	6×29.2	$\frac{1}{4} \times 14$		6354.46		6345.12	0.15	6367.62	0.21	6283.37	1.12	6936.30	9.00

fire it instantly goes out. Fire cannot melt it. It will file, drill, tap and polish like a piece of hard rubber or iron. I do not think the weather affects it at all.

THE CALCULATION OF PLATE GIRDERS.

BY A. MUENSTER, MEMBER CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read October 3, 1887.]

I submit herewith to the Society the result of some recent investigations as to the reliability of the formulas in use at the present for the calculation of flange stresses in plate girders. At the same time I take the opportunity to present to you three new formulas for the same purpose, which, I hope, may prove useful to the profession. I have for some time been well aware of the incorrectness of the results obtained by the formulas commonly used for the calculation of plate girders (formulas 5 and 6 in the table), but their universal use by the profession led me to think that the errors would be so small that they needed not to be considered in practice. It was only of late that I became aware of the magnitude and variable nature of the differences from values obtained by calculation of the moment of inertia of section. That the percentage of error is not constant, or nearly so, but varies greatly with the proportions of web, flange angles, and plates relative to each other, is of course the great objection to the use of these two formulas. If this was not the case the error might be neutralized by the introduction of a constant or by so choosing the unit strain as to compensate for the difference. As it is, the actual strain in a beam proportioned after these two formulas may vary up to 30 per cent. from what was intended by the specifications.

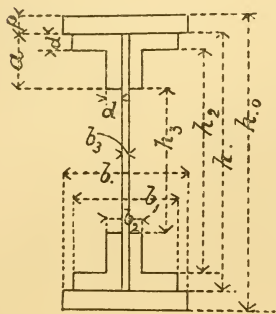
The moment of resistance, as obtained from the calculation of the moment of inertia of section, gives the nearest approximation to a correct value of the strength of a beam that we can arrive at, and when it is desired to use formulas of only approximate correctness, on account of the labor involved in the former method, the aim should be to deduce a formula giving results which would agree as closely as possible with the values obtained by the method of the moment of inertia.

In the accompanying table I have given the moments of resistance, in inch pounds, for 50 sections of beams, from $\frac{5}{16} \times 12$ inches web and flange area of 2.94 square inches up to $\frac{3}{8} \times 72$ inches web and flange area of 87.52 square inches.

To test the quality of the formulas, as extreme cases as are ever likely to occur in practice have been included among the examples. As it would not alter the results of the different formulas relative to each other, no reduction has been made for rivet holes. The moment of resistance as calculated from the moment of inertia of section is given in column 1, and is taken as the standard of comparison. The results obtained are given in the following columns in the order of their accuracy, and the percentage of error given for each example. Turning to

columns 5 and 6 of this table we find the old formulas $F \times h_1 = R$, $\left(F + \frac{W}{6}\right) \times h_1 = R$, where F = flange area, W = area of web and h_1 = distance c. to c. of gravity of flanges. We find that the results from formula No. 5 lie uniformly above the correct ones, and have a maximum percentage of error of 11.1 per cent. in this series of examples. By using this formula, then, the actual unit strain would always be larger than contemplated by the specifications, and the beam consequently inferior in strength. Formula No. 6 gives values for moments of resistance as uniformly below the true ones as No. 5 gave above, but with larger differences yet, the percentage of error in one of our examples being as much as 29.5 per cent. Under certain proportions of web, flange angles, and flange plates to each other, we see that both formulas give correct results; but it will also be found that this happens only under certain extremes of conditions.

When the above facts once are brought to the notice of engineers, there seems to me to be no longer any excuse for using formulas giving such rude approximations to the true values, even if it should be necessary to figure out the moment of inertia of section for each case. Fortunately there is no necessity for using this slow method, as formulas can be deduced fulfilling all practical requirements as to ease of application and correctness of results.



the distance c. to c. of gravity of flanges, in many cases to be arrived at only after a tedious calculation. The other quantities, area and depth of flange angles and thickness of flange plate, are also quantities known without extra figuring. The mean error of this formula is only 0.35 per cent. Formula No. 3 gives results practically as correct as formula No. 2 (the mean error being 0.57 per cent.) and contains the same quantities only as formulas 5 and 6. It is simple of form and not more tedious of application than the former two. Formula No. 4 is exceedingly simple in form and application and gives fairly accurate results. The average per cent. of error for the whole number of examples is 1.71 as compared with 4.89 and 10.72 for formulas 5 and 6 respectively. I have given this formula a place with the others, as its simple form may make it useful in preliminary work. As would be expected from the results obtained, formulas 2 and 3 are both rational. For those interested I give below the deduction of the formulas.

Formula No. 2 is deduced from the general expression below of the moment of inertia of any section of plate girder. See figure.

$$\text{Moment of inertia} = J = \frac{1}{12} \left[b (h_0^3 - h^3) + b_1 (h^3 - h_2^3) + b_2 (h_2^3 - h_3^3) + b_3 h_3^3 \right]$$

$$\text{Moment of resistance} \frac{2J}{h_0} = R. \quad (\text{Inch lbs.})$$

If we in the above expression substitute $h_0 = (h + 2p)$, $h_2 = (h - 2d)$ and $h_3 = (h - 2a)$, develop the third powers of these sums, and omit the third powers of the fractions $\frac{p}{h}$, $\frac{a}{h}$ and the second powers also of $\frac{d}{h}$, which are very small quantities, we get the following equation :

$$(I.) \quad R = \frac{1}{6(h+2p)} \left\{ 6bh^2p - 12hp^2b + 6b_1h^2d + b_2(6h^2a - 6h^2d - 12ha^2) + b_3(h^3 - 6h^2a + 12ha^2) \right\}$$

Resolving the polynoms and summing up the terms representing the areas of web and flanges, we have

$$(II.) \quad R = \frac{1}{6(h+2p)} (6h^2F + h^2W - 24ha^2d + 12hp^2b).$$

$$(III.) \quad = \frac{1}{1 + \frac{2p}{h}} \left\{ \left(F + \frac{W}{6} \right) h - A \times a + 2P \times p \right\}$$

where $4ad = A =$ area of angles in one flange (nearly so) and $p b = P =$ area of plates in one flange.

Total flange area = F , area of web = W .

Transforming $\frac{1}{1 + \frac{2p}{h}}$ into $\left(1 - \frac{2p}{h} \right)$ performing the multiplication,

and omitting $\frac{1}{6} W \times 2p$, and also the products of $\frac{2p}{h}$ into the last two terms of equation (III) we get our final formula :

$$R = \left(F + \frac{W}{6} \right) h - A(a + 2p).$$

Formula No. 3 is deduced from the following expression for the moment of resistance of a section of a plate girder.

$$(I.) \quad R = \frac{4I + \frac{2Fh^2_1}{4} + \frac{bh^3}{12}}{\frac{h}{2}} =$$

$$(II.) \quad \frac{8I}{h} + \frac{Fh^2_1}{h} + \frac{bh^2}{6}$$

$R =$ moment of resistance (inch lbs.).

$F =$ area of each flange.

$W =$ area of web = $b \times h$.

$h =$ distance out to out of flanges.

$h_1 =$ distance centre to centre of gravity of flanges.

$h - h_1 = d$.

$I =$ moment of inertia of flange angle with reference to axis through its centre of gravity.

If we, in the foregoing equation, neglect the term with "I" as being very small compared with the rest of the expression, we have

$$(III.) \quad R = F h - 2 F d + \frac{F d^2}{h} + \frac{W h}{6}$$

$$(IV.) \quad = \left(F + \frac{W}{6} \right) h - F d \left(2 - \frac{d}{h} \right)$$

omitting $\frac{d}{h}$ in the last term of equation (IV.) as it always will be a small quantity compared with "2," we get the formula :

$$(V.) \quad R = \left(F + \frac{W}{6} \right) h - 2 F d.$$

I wish to acknowledge my indebtedness to Mr. Karl L. Lehmann for valuable assistance in this work.

THE RELATIVE ECONOMY OF HAND AND MACHINE DRILLING.

BY H. A. WHEELER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May, 1887.]

In the following comparison between hand and machine drilling, the discussion is limited solely to the question of economy. The very much greater speed obtained by the use of machines, which so frequently is of paramount importance in tunnel and railroad work, is not considered. Nor is the much greater capacity of a machine plant regarded, though frequently in mining practice a maximum production from limited working faces should be obtained, in order to keep the rest of the plant in full operation. The secondary action of air-drills as ventilating machines must also be passed over, while the ability to accomplish the same amount of work with fewer men by the use of machines is also ignored, though in time of labor troubles this is not an unimportant item. These are considerations that, in not a few instances, may outbalance the question of economy, and such cases must be decided on their individual merits. The attempt herewith made is to discuss which is the more desirable system from the single standpoint of a minimum outlay to accomplish the drilling.

Since the mechanical improvements in the more recent drills have made it necessary to have only about one extra drill in the repair shop for every ten in use, while in earlier practice from three to seven drills were required in order to keep one drill in constant operation; and as the source of power is coal or wood, as opposed to meat and flour, the popular impression is that machine drilling is always cheaper than hand work; while not a few have the idea that the economy approaches the ratio of the speed of machine over hand work. As a machine outfit will drill from two to six times as much in a day as a hand gang, the only question would seem to be, how much cheaper is machine drilling over that by hand, where the amount of work involved justifies the outlay for a machine plant.

Considerable miscellaneous data is to be found that seems to justify the

exaggerated idea of the great pecuniary advantage of machine drilling, and figures (from disinterested sources) are cited from actual work that apparently leaves no doubt on this question. Much of this data is, however, quite untrustworthy, as quite important items of the true cost of machine run plants are underestimated or quite overlooked. One of the least reliable of the heavy items of expense in running drills, as given in published exhibits, is the repair and renewal account. For while the expenses of the machine shop should be readily obtained, including the extra blacksmithing, the repairs, renewals and extensions of the pipe lines are not apt to be included; and if the compressor repairs are charged to the drill account, the repairs and renewals of the boiler plant, or the pro rata for the drill department, if a general steam plant is used, are very apt to be mischarged to another account. But of still greater importance, even if all of the very numerous repair and renewal charges for the entire plant devoted to running the drills are properly debited, the repair expense is often erroneous from being drawn from the experience with a comparatively new plant (perhaps just after changing from hand working, when such comparisons are most frequently made), which is very much less than when drawn from the average of a time sufficiently long as to represent the mean life condition of the plant. Of the legitimate items of expense that are so often overlooked, are the annual charges against the machine plant for insurance, interest and sinking fund. As loan rates on mining and contract paper are high, the interest charge is no small matter, while a sinking fund to repay the principal sunk in the plant, when it is worn out or abandoned, is rarely considered, though this is quite as essential in arriving at the *true cost* as the wages, fuel or other factors that make up the ultimate expense. An additional charge to be placed in the interest and sinking fund account besides the bare cost of the machinery delivered on the grounds, is the cost of building and erection of the plant, including the housings, which is an essential though very variable factor of the initial outlay.

While these items are usually insignificant in hand practice, and can be neglected without serious error, they are large and important factors in machine practice, and results given in which they are ignored will be much below the true cost.

In undertaking a detailed practical comparison of the two systems, we are at once beset by a very uncertain but exceedingly important factor in the character of the rock in which the drilling is done. The nature of the rock affects the speed of drilling to such an extreme degree that we are practically reduced to narrow our comparisons to places where both systems are used on the same rock; and to eliminate the variations due to personal equation, the data should be drawn from a number sufficiently large to give average results as to capacity.

Another requisite for a fair comparison is that the workings should be large enough to permit the proper handling of the machines, for they cannot be judiciously used in some contracted places that occur in mining practice, where it may be inexpedient to so enlarge the workings as to allow their introduction. Where there is ample room for using ma-

chines, hand drilling will still have the advantage on account of being able to place the holes better, to more favorably take advantage of weak points of the rock, on account of the clumsy, less adaptable character of the machine supports.

This will show itself in a smaller consumption of powder and fewer feet of drilling required per cubic yard of rock removed, than if done by machines. While this difference will be very slight in working large, well-opened stopes or wide bench workings, it will be very apparent, in favor of the hand system, in narrow workings, as drifting or heading driving, where the judicious placing of the holes will result in necessitating fewer of them, and in bringing down heavier burdens for each shot. In rare cases, as at Flood Rock, where all the holes for the big blast (aggregating 113,102 lineal feet) were "uppers," or roof holes, averaging ten feet in depth by three inches in diameter, the machines would have a decided natural advantage over hand work, from the difficulty of boring such large holes by hand, where they all point upward. When the conditions are similar under which the two systems are carried on and favorable for a fair comparison, we have the following elements to consider in arriving at their comparative economic values.

I. The somewhat cheaper class of labor for hand drilling as compared to machine drillers. While in some districts good hammersmen are paid quite as well as machine runners, in most cases there is a difference of 10 per cent. to 20 per cent. less in favor of hand drillers.

II. The drill sharpening is cheaper in hand drilling, as the simple chisel-shaped bits are more easily and quickly sharpened than the +, X, and Z-shaped machine bits. In the quarry practice of St. Louis hand bits are sharpened by contract for 5c. to 7½c. apiece, while machine bits cost 20c. to 25c. each; but as the machine bit exposes two to three times as much cutting surface, this will show a saving of about 50 per cent. in favor of the average hand bit.

III. The small amount of capital required to purchase a hand plant compared with that required to purchase a machine plant. A single hand plant will cost \$5 to \$20, while the simplest kind of a machine outfit for a single machine, when steam is used, involves an outlay of at least \$700; and if the work is under ground, necessitating the use of air, the outlay will be much larger. This requires not only a much larger capital, but there will be a fixed annual charge for interest on this capital for its use, and insurance on the plant against fire, that must be paid by the drill out of its saving over the practically non-interest bearing hand system, for the small outlay in the hand plant makes its interest charge per foot of hole a very insignificant item.

IV. As a sinking fund charge to repay the principal invested in the two plants there will be a heavy charge against the machine system, while it will be insignificant in the other, in the respective ratios of the capital involved in each. The average lifetime of a machine plant, which will have to be assumed, will be a very variable quantity, whose value can only be approximated. For a well built plant, carefully taken care of, will show a much longer life over another that is cheaply built and neglected; yet in either event the cost must be repaid during its lifetime, making a much heavier charge for a shortlived plant than where the

same money can be paid back over a longer time. A fair life for an ordinary plant is assumed to be about ten years, where it is kept properly repaired.

V. Repairs are a very heavy item of expense with a machine plant, and very light with a hand plant, generally not exceeding \$5 per year. It is an outlay that, besides local conditions, will be strongly influenced by the personal equation of the men in charge, and of the particular kind of machinery used, and hence will fluctuate widely. It is also a difficult item to obtain with accuracy, as, unfortunately, few establishments so keep their books that every expense, whether for labor or raw material, is charged to its proper ledger account. It is not surprising then to find the annual repair account varying from \$25 to over \$400 a year for each machine drill employed. Usually it will require an outlay of \$150 to \$200 per year, and in mining practice, where the drill usually works both night and day, a careful average for a long period of time will show an annual expense approximating \$400 per year. Nor does this include pipe, receiver and compressor outlays, where compressed air is employed, which will be an additional outlay of \$50 to \$500 per year, according to the size and character of the plant, while boiler supplies and repairs will cost from \$25 to \$1,000 more.

VI. Fuel expense will be confined to machine plants, and will be another very variable quantity; for while large well designed plants can run on a coal consumption of one-quarter to one-fifth ton per drill per shift, small plants with long lengths of bare steam pipe will show a consumption of one ton per drill.

The labor of firing the boiler and running the compressor, if air is used, have also to be added, which, according to circumstances, will be another expense of \$1.50 to \$5 per shift. Supplies, as packing, oil, waste, etc., cause an additional small daily outlay of 10 cents to 20 cents a drill, and if a compressor is used, 25 cents to 50 cents more per diem must be added; while if the work is underground candles or oil for lighting will cost 5 cents to 15 cents a shift, which also applies to hand work.

VII. Before considering the question of speed, it is necessary to recall the fact that the time actually utilized per shift in drilling is largely in favor of hand work. For the time lost in swabbing out the sludge, changing bits, starting new holes, etc., in hand working does not usually exceed 15 to 20 per cent., leaving 80 to 85 per cent. available for drilling; while with machines 30 to 60 per cent. of the time will be thus lost on account of the much longer time necessary to set up and take down the drill, change bits, etc.

The harder the rock the less frequently will the follower bits require changing, or the drill have to be shifted for new holes, and therefore the greater will be the time effectively used in drilling; yet under ordinary conditions the drill will be idle at least 40 per cent. of the time, and more probably over 50 per cent. when allowance is made for blasting. Notwithstanding this much greater enforced idleness, the speed or feet of holes drilled per shift is much greater in machine than in hand practice, and will usually vary, according to local circumstances, from two to six times as much per gang.

The heavy blow so rapidly repeated by rock or percussion drills is so effective in penetrating the rock that it will generally accomplish four* times as much work per shift as a hand drill, in spite of the much larger percentage of time lost by inaction.

As the energy is produced by steam, as against man power, we can at once appreciate the popular tendency to jump to the conclusion that it must of necessity do its work decidedly cheaper than the much slower man power method, notwithstanding the extra outlay required for the plant. But the item of repairs, on account of the destructive nature of the work, is so heavy, the loss of power is so large from condensation, leakage and in the intermediate compressor, the size and awkwardness of the drill supports are such that we are not always so well able to take advantage of the weak points in the rock, and as the system of attack cannot be quite so advantageously carried on as by hand, we have to carefully consider each element of the previously mentioned factors of cost before we can positively decide in favor of the economy of the machine system in any given case. Every place should be carefully discussed according to its individual conditions, which will be found to vary so much as to make any generalizations, as in a paper like this, of only proximate value.

If the work was being carried on in an open quarry, where steam could be used, and the pipes were well lagged; if the rock was very hard to drill, so that the percentage of time lost by inactivity would be small; and if labor was high and fuel cheap, then there would undoubtedly be economy in the use of machines that might amount to from 15 per cent. to 40 per cent. in their favor per foot of hole drilled. If, however, it was underground work, in easy drilling material, where compressed air and a long line of piping would be needed, the economy would be much less; and if labor was very cheap and fuel high, hand drilling would be cheaper by 5 per cent. to 25 per cent.

The relative value of each factor of the complete cost of drilling is best seen by citing practical cases where both systems are worked side by side under identically the same conditions, though such figures will vary considerably among themselves (aside from all market changes) on account of local conditions.

Such an example is to be found in the quarry practice in the horizontal, regular bedded limestone quarries of St. Louis, which are worked as large free benches. The rock would be classed as easy drilling, for while some of the ledges contain considerable flint, rendering the drilling slow and difficult, other ledges are argillaceous and easily penetrated; and the average work is in a free-drilling, readily penetrated, compact limestone. The machines used are the 3-inch dynamic or Ingersoll pattern, run by steam on tripods, and are worked by one man, who is occasionally aided by a laborer when the drill needs much shifting. All the plants are very small, running only one to three drills each, and will average about nine months of steady work during the year. The drill

*In considering speed, the normal working conditions are assumed and average results are taken; the very high speeds recently attained in special work, where every factor conducive to speed was the main consideration, are ignored as being misleading when compared with ordinary practice.

repairs are exceedingly light, surprisingly so when compared to tunnel or mine practice, which is due to: (a) Close supervision, the quarries being largely bossed by the owners themselves. (b) The very favorable conditions, in a good light, under which they work. (c) The small amount of time during which they are drilling, as they work only one shift for less than nine months of the year and are idle at least 50 per cent. of the shift. (d) The exceptionally careful lot of men who run the drills.

ST. LOUIS QUARRY PRACTICE.

Average Cost of Hand Drilling per Foot.

	Per day.	Percentage of whole.
1 driller	\$2.500	97.6
Sharpening one bit	0.050	2.0
Repairs to jumper	0.004	0.2
Interest at 10 per cent. on \$6 for $\frac{1}{225}$ year	0.0025	0.1
Sinking fund, do	0.0025	0.1
Total	\$2.559	100.0

Or, $\frac{\$2.559}{10 \text{ feet}} = 25\frac{59}{100}\text{c. per foot by hand drilling.}$

Average Cost of Machine Drilling per Foot.

	Per day.	Percentage of whole.
1 drill runner	\$2.75	36.4
1 helper, $\frac{1}{10}$ day, at \$2	0.20	2.7
12½ busb. coal at 8c	1.00	13.2
Oil, packing, etc.	0.15	2.0
Sharpening 1½ bits, at 25c	0.38	5.0
1 fireman	1.75	23.1
Repairs—Drill	\$60	
Boiler	37	
Hose, etc.	23	
\$120 per $\frac{1}{225}$ of year	0.53	7.0
*Interest on \$905, at 10 per cent., for $\frac{1}{225}$ year ..	0.40	5.3
Sinking fund on \$905, at 10 per cent., $\frac{1}{225}$ year ..	0.40	5.3
Total	\$7.56	100.0

Then $\frac{756}{37.5} = 20\frac{2}{15}\text{c. per foot by machines.}$

* Investment in one drill plant.

1 boiler with fixtures	\$400
1 3¼ inch drill, with tripod	345
300 feet 1 inch pipe	18
Tools	20
2 sets bits	22
Erection	100
Total	\$905

The machines will bore about $37\frac{1}{2}$ feet a shift, of $1\frac{1}{2}$ to 2 inch holes.

In the estimate the data is given on the basis of per foot of hole drilled, as the ground is so easily attacked as to give hand drilling little if any advantage over the machine in the consumption of powder or feet of drill holes required. The hand drilling is all done with jumpers or by the vertical fall of the drill bar. A driller will average about ten feet of $1\frac{1}{2}$ to $1\frac{1}{2}$ inch diameter holes per shift of ten hours.

As the average St. Louis limestone is not a hard drilling rock, this is a very favorable exhibit in favor of machines, especially as the machine practice is not developed on a sufficiently large scale for an economical fuel consumption.

CONGLOMERATE MINE PRACTICE.

Average Cost of Hand Mining per Foot.

	Drifting.		Shaft sinking.	
	Per lineal foot.	Percentage of whole.	Per lineal foot.	Percentage of whole.
Wages by contract.....	\$13.238	81.5	\$13.469	81.2
Blasting supplies	2.561	15.8	2.630	15.9
Drill sharpening.....	.436	2.7	.495	2.9
Total.....	\$16.235	100.0	\$16.594	100.0
Average distance driven per month.....	26.8 feet.		23.6 feet.	

Repairs, interest and sinking fund were not given; but as these are so small in hand plants, no serious error is made in omitting them.

CONGLOMERATE MINE PRACTICE.

Average Cost of Machine Mining per Foot.

	Drifting.		Shaft sinking.	
	Per lineal foot.	Percentage of whole.	Per lineal foot.	Percentage of whole.
Wages by contract.....	\$5.776	37.4	\$9.300	44.4
Blasting supplies.....	4.004	19.5	4.092	19.5
Running compressor.....	1.410	9.1	1.850	8.8
Repairs to compressor.....	0.120	0.9	0.160	0.9
Sharpening bits.....	0.338	2.2	0.51	2.4
Repairs to drill.....	0.630	4.1	0.83	4.0
Interest on \$62,740 plant, at 10 per cent.....	1.580	10.2	2.10	10.0
Sinking fund, at 10 percent..	1.580	10.2	2.10	10.0
Total.....	\$15.438	100.0	\$20.932	100.0
Average distance driven per month.....	$43\frac{1}{10}$ feet		$32\frac{5}{10}$ feet.	

The excellent duty of $37\frac{1}{2}$ feet per day, and the very low repair account are exceptionally good, and due to the fact that the quarry owners do their own bossing. This very favorable state of affairs would be lost in a big plant, which would largely counterbalance the lower fuel ex-

pense resulting from such enlargement. So the St. Louis rock, as worked in free, dry, easy working quarries, with high labor and cheap fuel, can be drilled from 20 per cent. to 25 per cent. cheaper by machines.

Another case illustrating mining practice in hard drilling rock is the Conglomerate Mine in the Lake Superior copper region, which works a hard quartz porphyry conglomerate. This mine was originally worked by hand, and subsequently a Rand compressor and sixteen 3-inch Rand drills were introduced, with the cessation of all hand work. The machine figures cited are drawn from the first year's work, when the repair account would be very light; in fact, the drill repairs only amounted to \$150 per drill for the year. The compressor plant was well built, and averaged $\frac{1}{2}$ cord of soft wood per drill per shift. The data is all calculated on the lineal feet of drifts or shafts driven per month, as it is on that basis that the work is contracted out to the miners.

Here we have drifting by hand costing \$16.23 per foot, while it is done by the rock-drills for \$15.44, or 5 per cent. less. The shaft sinking costs \$16.59 by hand and \$20.93 by machine, or 25 per cent. more. It should be noted that the rate of sinking is only 10 per cent. slower than drifting in hand practice, and the expense only 2 per cent. greater, while it is 25 per cent. slower and 25 per cent. more expensive in machine practice, on account of the extra amount of time lost by the inaction of the drill in this particular class of work, which is one of the least favorable for *economic* machine work.

Another mining case, at the Northwest Copper Mine, Lake Superior, in a rather soft copper bearing amygdaloid, that drills readily, gives the following figures:

NORTHWEST MINE PRACTICE.

Cost of Drilling per Foot.

	By hand.		By machine.	
	Per foot.	Percentage of whole.	Per foot.	Percentage of whole.
Labor and blasting supplies by contract.....	\$11.43	99	\$9.01	75.8
Interest at 10 per cent.....	.....	.....	.62	5.2
Sinking fund at 10 per cent...	.....	.....	.62	5.2
Running compressor, repairs, etc.....	.....	.....	1.64	13.9
Total.....	\$11.43	100	\$11.89	100.0
Speed per month.. ..	21.07 feet.		47.07 feet.	

This seems to show an increase of only 4 per cent. in the cost of machine over hand work in easily drilling ground. But the figures for the machine plant are based only on seven months work with a new plant, and hence the repair account is absurdly low. If the more probable figure of \$2 is taken instead of \$1.64, then it gives a difference of 7 per cent. in favor of hand working, which is nearer an average value. While the hand drift was 5 × 6 feet in size, it was necessary to enlarge it to

7 × 8 feet to run the machines, with a consequent gain of that much material in this case, as it was all ore bearing.

These three cases from actual practice are sufficient to not only bring out the values with the variation of each item as regards its percentage of the whole cost, but quite fully show the danger of sweeping assertions as to the invariably greater economy of machine practice.

For while machines will generally do the work cheaper, and at times considerably more so, in not a few instances there will be a decided economy in favor of hand drilling; while in many cases a carefully drawn-up cost sheet will show but a trifling difference either way as regards the sole standard of economy. Hence for any given problem where the financial consideration is to be the deciding standpoint, it will be necessary to carefully weigh the local factors previously considered before a reliable decision can be made as to which system will do the work more economically.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 18, 1888 :—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 7:45 P. M., President Rice in the chair. Thirty-one Members and eight visitors present. The record of the last meeting was read and approved.

Messrs. Otis F. Clapp, Isaac K. Harris, Waterman Stone and D. W. Pratt were elected Members of the Society.

The following were proposed for membership : Joseph Coulson, Jr., of Boston, recommended by M. T. Cook and E. W. Howe ; C. Atherton Hicks, of Needham, recommended by E. A. W. Hammatt and F. W. Hodgdon ; and John H. Webster, of Boston, recommended by J. A. Tilden and G. A. Bobrick.

The Secretary read a letter from Mr. Arthur V. Abbot acknowledging the receipt of the vote of thanks passed at the last meeting.

A communication was also read from the Civil Engineers' Association of Kansas in relation to the interchange of proceedings. Later in the evening, upon motion of Professor Lanza, the President was authorized to reply to the communication in behalf of the Society.

The President announced the appointment by the Government of the following Committee to extend courtesies to the American Institute of Mining Engineers at its coming meeting in this city : L. F. Rice, William Jackson, Seth Perkins, Thomas J. Young and W. S. Chaplin.

Mr. Jerome Sondericker read a paper entitled "An Investigation as to How to Test the Strength of Cements." Portions of the apparatus designed and used in the Laboratory of Applied Mechanics of the Institute of Technology for testing both the compressive and tensile strength of cement were exhibited and the new features fully described. The paper was discussed in a letter read by the Secretary from Mr. Ball, and by Messrs. Allen, Clarke, Lanza, Rice, Smith and Stearns.

[Adjourned.]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

JANUARY 4, 1888:—284th Meeting.—The Club met at 8:15 P. M. at Washington University, President Holman in the chair, twenty-four Members and two visitors present. The minutes of 283d meeting were read and approved. The Executive Committee reported its meeting of the 4th inst., announcing the resignations of J. W. Hill, and approving the applications for Membership of Robert H. McMath, J. W. Schaub, Jas. M. Sherman, A. W. Hubbard and Jos. F. Porter. They were balloted for and elected. The application for Membership of Malvard A. Howe, indorsed by J. B. Johnson and H. B. Gale, was referred to the Executive Committee.

The paper by Mr. Charles H. Ledlie, entitled "Construction of Dam and Reservoir at Athens, Ga.," was then read by Professor Johnson. The method of carry-

ing out the work was given in detail, and sketches of the principal features were submitted. The protection of this kind of work against crawfish and musk rats was shown to be of prime importance. Colonel Moore, Messrs. Holman, Johnston and Flad took part in the discussion.

Professor Nipher then read a paper on "The Volt, the Ohm, the Ampère—What are They?" being a mathematical discussion of the subject. The results were shown, and their value to the electrical engineer explained. The paper was illustrated by suitable apparatus and drawings. Messrs. Holman, Flad, Moore and Seddon participated in the discussion. Papers by N. W. Eayrs and Prof. C. C. Brown were announced for the next meeting, January 18.

[*Adjourned.*]

W. H. BRYAN, Secretary.

JANUARY 18, 1888 :—The Club met at 8:20 P. M. at Washington University, President Holman in the chair, eighteen Members and four visitors present. The minutes of the 284th meeting were read and approved. The Executive Committee reported its forty-sixth meeting, approving the application for membership of Malvered A. Howe. He was balloted for and elected. An application for membership from Bathurst Smith was announced, indorsed by J. A. Seddon and F. E. Nipher. It was referred to the Executive Committee.

The Secretary read a communication from the Civil Engineers' Association of Kansas on the subject of interchange of papers and proceedings.

Prof. Johnson called attention to a pamphlet by J. A. L. Waddell on the subject of improvements in the construction of highway bridges. On motion it was ordered that a committee of three be appointed to consider same with a view to indorsing the author's ideas. The chair appointed as such committee J. B. Johnson, Robt. Moore and N. W. Eayrs.

Mr. N. W. Eayrs then read a paper on "The Improvement of Nantucket Harbor, Mass." The sandy coast rendered the work slow and difficult, as only the scouring effect of the tide was available. Great difficulties had been met with, but good results were already apparent. At the beginning a mean channel depth of only 6 feet was available. This had already been increased 18 inches, and the plans contemplated an ultimate mean depth of 12 feet and possibly 15; discussed by Messrs. Ockerson and Wheeler.

The Secretary read a paper by Prof. C. C. Brown, of Union College, Schenectady, N. Y., on "State Surveys." The author showed the great necessity for more careful and detailed surveys, their probable cost, and the best methods of undertaking same.

Prof. Nipher exhibited another specimen of cast-iron cap burst by hydraulic pressure caused by firing a rifle ball into a cylinder of water, the bottom of which was closed by the cap.

Mr. Crow exhibited an improved form of radial draw-bar as adapted for cable car service.

[*Adjourned.*]

W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JANUARY 3, 1888 :—The annual meeting (243d of the Society) was held at 7:30 P. M. at the Tremont House, Chicago.

In the absence of President Artinfgstall, Mr. D. J. Whittemore was elected president *pro tem*.

On motion of L. E. Cooley, a special order of business was adopted for the meeting.

The minutes of the preceding meeting were read and approved. The Secretary announced that he had sent out the notices for the annual supper in accordance with the arrangements of the Committee appointed for that purpose. This Com-

mittee would present the results of its efforts at the close of the business meeting. He also reported that the Committee on Nominations had submitted a list of nominees for the ensuing year, and that letter ballots had been sent out and 85 votes received from Members.

On motion, three tellers, B. Williams, C. McRitchie and M. Lassig, were appointed to open the ballots and canvass the vote and to report later in the meeting.

Applications for membership were received from Elmer L. Corthell, civil engineer ; Charles Poor, civil engineer ; William T. Casgrain, civil engineer and contractor.

The Secretary announced the resignation of W. L. B. Jenney, Chicago, Illinois ; L. W. Goddard, Escondido, California ; A. F. Robinson, St. Paul, Minn.

Also, that Mr. E. C. Carter, who had temporarily retired, had applied for reinstatement, and been placed on the list.

Annual reports were called for from the several officers.

The President's report was postponed from sickness.

The Secretary reports as follows :

ANNUAL REPORT OF SECRETARY FOR 1887.

During the past year eleven meetings have been held and eleven written papers have been presented. Sixteen Members have been added to the Society, making a total of 196 now on the rolls.

The receipts have been \$760.00, which, added to the amount on hand at the beginning of the year, \$70.05, makes a total of \$830.05. The amount paid out is \$791.65, and unpaid bills amount to \$86.00, showing that the Society is indebted for \$47.60. More than this amount, however, can probably be collected from the 40 Members whose dues are now delinquent.

In the Annual Report of the Secretary for the year 1886 it was stated that, with the annual dues at five and six dollars, the Society must have at least 300 members to secure a suitable revenue. The dues were reduced to these small amounts, as a matter of experiment, in hopes that a membership of at least 300 could be secured. Thus far the experiment is a failure, and the question must at once be met, whether we shall attempt to increase the number of Members, or shall return to a system of larger annual dues.

Inasmuch as we have a fixed expense of \$3.00 per Member, as our portion of the cost of publishing the JOURNAL, we have only \$2.50 per Member left to apply for other expenditures. To raise \$750.00 for these, we require 300 Members at the present dues. One hundred Members at \$10.00 would give \$700.00, or about the same net result.

At the beginning of the year fifteen "Topical Committees" were appointed, comprising some 40 different persons, and the following letter was sent to each Member of every Committee:

"To the Members of Topical Committees :

"The printed minutes of the 234th meeting, enclosed herewith, will inform you of your appointment as Members of these Committees. The welfare of the Society depends largely on the number and character of papers and topics presented for discussion, and it is your duty to furnish material on the particular subjects assigned to your respective committees. You have authority not only to obtain papers from Members of the Society, but to present articles contributed by others whom you consider competent to instruct and interest the Society.

"The Member first named on each Committee is its Chairman, and it is his duty to put himself in communication with its other Members as soon as possible."

It was supposed that by placing the practical work of the Society, providing material for papers and discussions in the hands of so many committees, the best results could be obtained in that direction. A reference to the proceedings of the Society does not show that any one of these committees has ever acted, except that one made a report on a subject especially referred to it.

In October last I presented my resignation as Secretary, but as the Society has not yet filled the position, I have continued to act to the present time, December 6th. From the date of our organization in 1869, I have continuously held this office, and I cannot now leave it without expressing my high appreciation of the uniform courtesy and kindness which have been shown to me by every Member.

For many years I have had a more intimate knowledge of the affairs of the Society than any other member, and have therefore, perhaps, felt a larger interest in it than any other one. In the future no one will rejoice more heartily in its prosperity than I, and I have faith to believe, that both in the immediate future and in coming years, every one of us may take worthy pride in the Western Society of Engineers.

L. P. MOREHOUSE, Secretary.

FINANCIAL STATEMENT FOR 1887.

Cash in hands of Treasurer, January 1, 1887, per last report.....	\$ 70.05
Cash paid to Secretary for dues.....	760.00
Total.....	\$830.05
Paid for rent.....	\$180.00
“ “ library.....	18.00
“ “ printing and mailing.....	75.25
“ “ postage and stationery.....	46.90
“ “ express and exchange.....	2.10
Journal.....	469.40
(Due for JOURNAL.....\$6.00)	791.65
Cash on hand.....	\$38.40
In hands of Treasurer.....	\$29.90
“ “ Secretary.....	8.50
Dec. 6, 1887.	L. P. MOREHOUSE, Secretary.

Verbal reports were received from the Librarian and Trustees. Treasurer absent.

The Committee on Nominations submitted the following resolution as an amendment to the By-Laws:

Resolved, That the annual dues be, and the same are hereby increased to the following amounts, viz.:

Resident Members, \$8.50 a year.

Non-resident Members \$7.50 a year.

Also that an initiation fee of \$5 be paid by each person who hereafter becomes a Member, and that such amount must accompany each application for membership, but will be returned if applicant be rejected.

W. S. BATES,

For Committee on Nominations, Etc.

After a brief discussion, in which the desirability of some change was generally conceded, the resolution was laid over under the rules.

A communication was received from J. A. L. Waddell, calling the attention of the Society to his treatise on “General Specifications for Highway Bridges of Iron and Steel,” and requesting that the Society take some action in aid of the reforms which he is seeking to accomplish. The matter was referred to the regular Committee on Bridges to be hereafter appointed.

The tellers reported the following ticket as elected for the ensuing year, with one dissenting vote each, except for Secretary and Librarian :

President, A. Gottlieb.

First Vice-President, John W. Weston.

Second Vice-President, O. Chanute.

Secretary, L. E. Cooley.

Treasurer, W. S. Bates.

Librarian, G. A. M. Liljencrantz.

Trustee, O. B. Green.

After the announcement of the vote by the president *pro tem*, the officers were duly installed.

Mr. W. S. Bates, for the Committee on Annual Supper, reported that they had succeeded beyond expectations in carrying out the purposes of the Committee, and that the subsequent proceedings must speak for themselves. The supper is now ready.

On motion the meeting adjourned to the supper room.

L. E. COOLEY, Secretary.

The supper was partaken of by about fifty Members, and was pronounced such a success that many of those present hoped that such events might be of more frequent occurrence.

At its conclusion, Mr. De Witt C. Cregier, in behalf of the Society, presented to Mr. L. P. Morehouse an edition of the Encyclopedia Britannica. His remarks were felicitous, going back to the origin of the Society, and noting the fact that Mr. Morehouse and himself were the only Charter Members present, and that Mr. Morehouse had continuously held and discharged the duties of Secretary since its formation, seventeen years ago. Mr. Morehouse was entirely surprised at this testimonial and rose to the occasion in many happy remarks.

Speeches were made by the new President, Mr. Gottlieb, and by Mr. Whittemore. Judge Pendergast spoke for the "Bench and Bar," which in this case pertained to the removal of rock benches and sand bars in the proposed waterway from Lake Michigan to the Mississippi River.

After short speeches by others present the meeting adjourned at 12 P. M.

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' CLUB OF MINNEAPOLIS.

NOVEMBER 18, 1887.—A special meeting of the Club was held at City Hall 7:30 P. M., the President in the chair. Present, Messrs. Coppelen, Sturtevant, Deterly, W. W. Redfield, Turner, Rigby, Pardee and C. L. Redfield. The minutes of previous meeting were read and approved.

The several members appointed to look for permanent quarters reported that a room could be had at 10 North Fourth street, where the cost would not exceed heat, light and some alterations needed; also one at present quarters in Council Committee room; also one in Kasota block at a rental per evening; also one somewhat removed from the business center to be donated for one year by F. C. Deterly.

On motion, the President appointed Messrs. Houston, Coppelen, Sturtevant, W. W. Redfield, and Pardee a Committee to search farther for rooms and report at the next meeting.

The Committee to revise the Constitution (appointed at the June meeting) not having reported, and two of the Members having been unable to do the work of the Committee, was discharged and a new Committee appointed, consisting of Messrs. Sturtevant, Coppelen, Houston, Turner, and W. W. Redfield, with instructions to report at the next meeting. The Club was made a Committee of the Whole to discuss the merits of the constitution for the benefit of the Constitution Committee.

The Secretary was instructed to get the sense of the Members as to the day on which regular meetings should be held and report at next meeting.

Mr. Coppelen announced that he would read a paper at the December meeting on "Bridge Foundation in the Mississippi River at Minneapolis and St. Paul."

[Adjourned.]

WALTER S. PARDEE, Secretary.

NOVEMBER 25, 1887.—A regular meeting was held at 7:30 P. M., City Hall. Present: The President and Messrs. Sturtevant, W. W. Redfield, Houston, Huntress, Coppelen, Crary, Crisman.

The Committee on Rooms, appointed at last meeting, reported that it seems advisable to retain, if possible, the present quarters, and to that end the committee recommends that the proper city officers be seen and the quarters secured. The committee further recommend that a committee be appointed to secure, if possible, permanent quarters in the new Library Building. Report was adopted and ordered filed.

The Committee on Revision of Constitution reported the Constitution as revised. The revised Constitution was read as a whole, then taken up section by section, discussed, acted upon and adopted.

The meeting adjourned until one week hence to consider the revised By-laws.

WALTER S. PARDEE, Secretary.

DECEMBER 2, 1887: An adjourned meeting of the Club was held at 7:30 P. M., at City Hall. Present the President and Messrs. W. W. Redfield, Coppelen, De-terly, Crisman and Pardee. The minutes of the last meeting were read and approved.

The Committee on Rooms reported that the City Committee on Public Grounds and Buildings offered the use of the committee room on the third floor of the City Hall, and approved of the placing of the Club library in said room. The report was adopted and on motion the offer of room accepted. A vote of thanks was extended to the Committee on Rooms for their successful work in obtaining rooms, and to the city officials for their kind offer.

The Secretary was authorized to pay two dollars each month to the janitor of the City Hall for services in keeping the room in order.

Mr. Coppelen reported that he would read his promised paper at the meeting of December 23 instead of December 9, as first intended.

The Club then took up the reading of the proposed revised By-laws, as a whole, and then discussed and adopted section by section. The revised Constitution and By-laws were adopted as a whole.

[Adjourned.]

WALTER S. PARDEE, Secretary.

DECEMBER 9, 1887:—A regular meeting of the Club was held at the City Hall, 7.30 P. M. Present: President Sublette and Messrs. Chrisman, Houston, Bra-ley, Hoag, Sturtevant, W. W. Redfield, Rigby, Pardee. Minutes of preceding meeting read and approved.

The Committee on Library Cases reported the excessive cost of any library cases in the market. The name of W. W. Redfield was added to the committee, and instructions were given to get designs for library cases and report at next meeting.

Mr. Sturtevant was appointed to see several delinquent members. Other delinquents were assigned to various members, with instructions to obtain a financial settlement before the next meeting.

The names of Frank Handy, vouched for by Messrs. Huntress and Sublette, and Geo. W. G. Ferris, vouched for by Messrs. Houston and Coppelen, were proposed for membership.

The Club then proceeded to the final reading of the revised Constitution. The Constitution as revised was voted upon and passed by a two-third vote, a quorum voting the said constitution. It having been voted upon and passed in a similar manner at the last meeting, the revised Constitution now stands adopted.

The new Constitution and By-laws were ordered prepared for the printer and filed with Secretary.

[Adjourned.]

WALTER S. PARDEE.

DECEMBER 23, 1887 :—A regular meeting was held at the City Hall, 7:30 P. M. Present, President Sublette and Messrs. Newman, Chrisman, Coppelen, Houston, Rinker and Pardee.

Minutes of the preceding meeting were read and approved.

The Committee on Finance reported the receipt of \$15.

The name of A. L. Hoff, C. E., consulting engineer, was proposed for membership; certified to by F. W. Coppelen and G. W. Sublette. Mr. F. W. Handy and Mr. Geo. W. G. Ferris, consulting engineer, Pittsburgh, were elected to membership.

The reading of Mr Coppelen's paper was deferred until next regular meeting.

[Adjourned.]

WALTER S. PARDEE, Secretary.

JANUARY 23, 1888.—A called meeting was held at the City Hall, 7:30 P. M. Present: Mr. President, Messrs. Houston, Coppelen, Riggs, Chrisman, Redfield, Braley, Crary, Sturtevant and Pardee.

On notice of Mr. Coppelen, amended by Mr. Sturtevant, the Club voted to accept an invitation of the St. Paul C. E. Club to visit the ice palace in St. Paul and have a social visit with said Club. Secretary was instructed to send invitations to all members, under the Constitution.

It was voted to appoint a committee of three to ascertain the probable number who will accept the invitation extended by St. Paul Club. Mr. President appointed Messrs. Sturtevant, Crary and Redfield committee, with instructions to report to Secretary before Thursday night.

Secretary read a letter from the Secretary of the Civil Engineers' Association of Kansas, with a reference to an interchange of club proceedings. It was voted to instruct the Secretary to correspond with the Secretary of the Kansas Club, and suggest to the members the advisability of their joining the Association of Engineering Societies, and that further action be taken by the Secretary as soon as a reply is received.

It was voted to make an extra effort to obtain a full attendance at the next regular meeting to assist in electing officers under the new constitution.

[Adjourned.]

WALTER S. PARDEE.

ENGINEERS' CLUB OF KANSAS CITY.

JANUARY 9, 1888:—A regular meeting of the Club was held in the club-room, at 7:45 P. M.

There were present: Messrs. Wm. B. Knight, J. A. L. Waddell, E. W. Grant, B. L. Manteller, A. E. Swain, W. Kiersted, E. B. Kay, C. G. Wade, T. F. Wynne, C. W. Hastings, G. W. Pearsons, John Donnelly, H. A. Keefer, E. W. Stern, D. W. Pike, Clift Wise, C. A. Burton, G. C. Stealey, R. C. Simons, K. Allen, and five visitors.

The minutes of the annual meeting and of the meeting of the Executive Committee were read and approved.

Ballots for the election of officers for 1888 were canvassed with the following results:

President, Wm. B. Knight; Vice-President, Octave Chanute; Directors, T. F. Wynne and W. H. Breithaupt; Secretary, Treasurer and Librarian, Kenneth Allen.

Mr. Fred. B. Tuttle was elected a Member.

On motion by Mr. Mason, it was voted to ballot for the following amendment to Sec. 2 of the By-Laws:

In place of "The annual dues shall be eight dollars (\$8) for Members and seven dollars (\$7) for Associate Members and Associates"—for the word "seven" substitute "five."

The resignation of the Treasurer, to take effect at the next regular meeting, was tendered, and on motion by Mr. Wade, accepted. Ballots for a successor resulted in the following candidates: J. A. L. Waddell, H. A. Keefer.

The Secretary read a communication from Mr. John Eisenmann, Secretary of

the Council of Engineering Societies on National Public Works, and presented for Mr. W. D. Jenkins a handsome framed photograph of the C., M. & St. P. Ry. bridge over the Missouri at Randolph, and for Prof. J. B. Johnson, of St. Louis, a copy of his Theory and Practice of Surveying.

The following were proposed as Members :

A. W. Boeke, by Wm. B. Knight and Kenneth Allen.

J. H. Lasley, by Wm. B. Knight and Kenneth Allen.

F. L. Miller, by R. C. Simons, C. M. Duncan and B. F. Booker.

The President then read his annual address.

[*Adjourned.*]

After the meeting the Club repaired to the Hotel Brunswick, where an excellent supper was served to 22 Members and 4 guests. Toast were responded to by Messrs. O. B. Gunn, John Donnelly, Wm. B. Knight, J. A. L. Waddell, G. W. Pearsons and others, and those who participated thoroughly enjoyed themselves until a late hour.

[*Adjourned.*]

KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

Arch, Stone, over South Street, Boston & Providence R. R. Gives description, with plan, elevation and sections of the stone arch of 40 feet span to replace the Bussey bridge. *R. R. Gaz.*, Dec. 30, 1887.

Axles, Steel Car. Abstract of a paper by John Coffin before the Philadelphia meeting of the American Society of Mechanical Engineers. *R. R. Gaz.*, Dec. 23, 1887.

Brakes, Freight Train. Gives a paper by Mr. Lauder, and the discussion that followed it at the December meeting of the New England R. R. Club. *R. R. Gaz.*, Dec. 23, 1887, also *Mast. Mechanic*. January, 1888.

—, *Suggestions of Radical Changes in Automatic Brakes*, especially for freight trains. The main feature of improvement suggested is that the power of the brake should increase with the load in the car. By A. K. Mansfield. *The Railroad and Engineering Journal*, January, 1888.

Bridge, Guard Rails. A circular issued by the Massachusetts Board of Railroad Commissioners to all of the railroads in that State, recommending a certain form of guard rail on bridges. *R. R. Gazette*, Dec. 30; *Eng. News*, Dec. 31; *Eng. and Building Record*, Dec. 31.

—, *Highway, General Specifications for, of Iron and Steel*. By J. A. L. Waddell. Discusses the present practice with its evils, and gives suggestions for better methods. Address the author, Kansas City, Mo.

—, *Lifting, Utica, N. Y.* By Squire Whipple. Gives description, with elevation and cross-section, of a "lift-draw-bridge" over the Erie Canal at Utica, N. Y. *Trans. Am. Soc., C. E.*, Vol. III., pp. 190-194.

—, *Lifting, Tarante, Italy*. Description of a bridge at Tarante, Italy, with plates showing details. It consists of two half arcs meeting in the centre when closed; each half has a rising and rotating movement, and is worked by hand or turbines. Distance between axes of rotation, 220 feet. *Engineering*, Oct. 28, 1887, *et seq.* Brief description, illustrated. *Sci. Am. Sup.*, Jan. 14, 1888.

—, *Mannheim*. Gives brief illustrated description of five competitive designs for a bridge at Mannheim. *Engineer*, Dec. 16, 1887.

—, *Proposed North River*. By G. Lindenthal. Gives brief description of the proposed bridge, also gives a full page plate comparing the bridge with four of the greatest bridges in the world. *Engr. News*, Jan. 14, 1888, and *Engr. and Build Rec.*, Jan. 14, 1888.

—, *Sin Ho, China*. Brief description, with elevations, cross section and half plans showing bracing of the Sin Ho bridge. *Engineer*, Dec. 9, 1887.

—, *Staging, Sukkur, India*. A brief description, with large colored plate of the staging for the main pillars and guys of the 820-foot cantilever span of the Sukkur bridge. *Indian Engineering*, Nov. 5, 1887.

—, *Suspension, Vishwamitri River*. Short description and abstract from specifications of a chain suspension bridge of 190 feet span, with two large plates showing elevation and details. *Indian Engineering*, Dec. 10, 1887.

ADVERTISEMENTS.

BOOKS FOR ENGINEERS.

NEWMAN, JOHN. Notes on Concrete and Works in Concrete. Especially written to assist those engaged upon works. The result of many years practical experience. 38 pages, 12mo, cloth, \$1.50.

DYE, F. Hot Water Supply : A practical treatise upon the fitting of hot water apparatus for domestic and general purposes. 81 pages, 12mo, cloth, \$1.00.

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INDEX DEPARTMENT

- Iron and Steel, Internal Stresses in.** By Gen. N. Kalakoutzky. A valuable series of articles giving results of original investigations. Discusses the determination of the influence of internal stresses, method of determining them, reduction, etc. *Engineer*, Dec. 9, 16, 23, 1887.
- Iron, Production of Pig, of a Definite Composition.** By H. Pilkington. Before the South Staffordshire Iron and Steel Institute. *Am. Manuf.*, Jan. 13, 1888.
- Iron, Wrought, Rerolling and Reheating.** Gives the results of experiments on the strength of wrought iron in bars and in chains; effects of different degrees of reduction in rolling, of reheating, rerolling and hammering; companion of chemical causes with physical results, correct form of test pieces, and miscellaneous investigations into the physical properties of rolled wrought iron. *Report of U. S. Board of Testing, Etc.*, Vol. 1, 1881, pp. 1-240.
- Irrigation.** By M. J. Mack. An interesting description of the Montezuma Valley, Col., with illustrated details of the irrigation works now being constructed. *Eng. News*, Dec. 31, 1887.
- *Machinery on the Pacific Coast.* A paper by John Richards, before the Institution of Mechanical Engineers. Describes the methods employed in irrigation, and then discusses the different kinds of machinery used. *Engineering*, Nov. 4, et seq. *Sci. Am. Sup.*, Dec. 17, et seq., 1887.
- Light-House, Rothersand.** By O. Offergeld, before the Association of Architects and Engineers, at Hamburg. Gives details of the construction of the Rothersand light-house in the North Sea, with two-page plate showing plans and sections of the pneumatic caisson. Valuable. *Engineering*, Dec. 2 and 16, 1887.
- Locomotive, Compound Tank.** Gives two-page plate of elevation and plan, with dimensions, and brief description of a freight locomotive, Webb's system and Joy's valve motion, for the London & Northwestern Railway. *Engineering*, Dec. 23, 1887.
- , *Express, C. & N. R. R.* Gives brief description, with two-page plate, giving sectional elevation, half plan and cross-section of a passenger locomotive for the Chicago & Northwestern Railroad. *R. R. Gaz.*, Dec. 23, 1887.
- , *Express, Mich. Cent. R. R.* Brief description, with drawings, showing sectional elevation, half-plan and cross-section of a standard eight-wheeled passenger engine for the Michigan Central Railroad. *Mast. Mech.*, Aug., 1887.
- , *Express, Midland R. R.* Two-page plate giving sectional plan and elevation, with dimensions of an inside cylinder, four-coupled type of express engine for the Midland R. R. Co. *Engineering*, Dec. 9, 1887.
- , *Express, N. Y., L. E. & W.* Gives double-page plate showing elevation and half-plan, also smaller drawing showing sections and details with dimensions. *Railroad Gaz.*, Jan. 6, 1888.
- , *Freight, C., B. & N. R. R.* Gives a two-page plate showing sectional elevation and half plan, other cuts showing cross sections of a ten-wheel locomotive of the Chicago, Burlington & Northern Railroad. *Master Mechanic*, December, 1887.
- , *Road, McLaren's High-Speed.* Describes a compound 12 horse power road engine working with a pressure of 175 lbs. *Engineer*, Dec. 16, 1887.
- Machine Construction, Milling Machines as a Substitute for the Planer in.** By J. J. Grant. Gives data relating to the cost of work on the two machines. Shows the milling machine to be the cheaper. *R. R. Gaz.*, Jan. 6, 1888; *Mech. World*, Dec. 17, 1887.
- Metallic Compounds.** A long list of authorities on metallic compounds may be found in the *Report of U. S. Board of Testing Iron, etc.*, Vol. I., 1881, pp. 149-210.
- Mining, Theory of Shot-Firing in.** By M. P. F. Chalon. Gives a general theory of shot-firing with common powder or high explosives. *Eng. News*, Jan. 14, 1887.
- Mineral Production for 1887, Statistics of.** Good summaries of the production and prices of zinc, copper, coal, coke and pig-iron for the past year will be found in *Eng. and Min. Jour.*, Jan. 7, 1888.
- Pavements, Asphalt and Concrete Foot.** By G. R. Strachan, before the Association of Municipal and Sanitary Engineers and Surveyors, at Leicester. Gives details of experiments with asphalt walks in England, with data of durability, cost, etc. *Sci. Am. Sup.*, Dec. 31, 1887.

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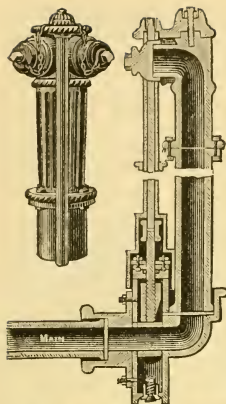
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- , *Specification for Material.* Gives specifications for the supply and delivery of wood blocks for paving portions of the street known as King's road and Pont street, in Parish of Chelsea. *San. Engr.*, Dec. 31, 1887.
- , *Specification for Wood.* Gives specifications for wood pavement in Parish of St. George, London. Said to be one of the best recently written. *San. Engr.*, Dec. 24, 1887.
- Piles, Protection of, from Limnoria and Teredo.** By M. Manson, before the American Society of Civil Engineers. Gives details of the treatment of piles for the Mission Street pier, San Francisco, by various methods, and the condition of piles after five years' service. An abstract in *San. Engr.*, Dec. 31, 1887.
- Pipe, Standard Pipe and Pipe Threads.** Report of a committee of the American Society of Mechanical Engineers, read at their New York meeting, November, 1876. Recommends the adoption of the Briggs standard, already in quite general use. *Transactions of the American Soc. of Mechanical Engineers*, Vol. VIII., 1887.
- , *Copper, Strength of.* Gives table of results of large number of tests made at the Lancefield Engine Works to ascertain some of the mechanical properties of the copper and brazing found in ordinary high-pressure steam pipes of large size. *Engineering*, Dec. 31, 1887.
- Power, Transmission of, by Ropes.** Gives illustrated description of the method of rope transmission adopted in the boiler shops of the Southern Railroad of France. *R. R. Gaz.*, Jan. 13, 1888.
- Pumping, Electric.** Brief description of an electrical pumping plant at St. John Colliery, Normanton, Eng. Efficiency, 44.4 per cent. *Engineer*, Dec. 2, 1887.
- , *Electric, in Collieries.* By Frank Brain, before South Wales Institute of Engineers. Gives details of the pumping plant at the Trafalgar collieries. Gives an analysis of the work done, showing the per cent. lost in different parts of plant; also gives comparison of cost of underground haulage by electricity, cables, compressed air and hydraulics. *Mech. World*, Dec. 24, 1887; *Am. Engineer*, Jan. 11 and 18 1888.
- Pumps, Mercurial Air.** By Prof. S. P. Thompson, before the Society of Arts. A very complete paper, tracing the development of the mercurial air pump. Gives cuts of the various machines and the results attained with some of them. *Jour. Soc. of Arts*, Nov. 25, 1887; *Sci. Am. Sup.*, Jan. 21, et seq., 1888. Abstracted *Engineering*, Nov. 25, 1887.
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- , *Inclined, Lookout Mountain.* By W. H. Adams, before the American Society of Mechanical Engineers. Gives full description of the inclined railroad up Lookout Mountain, Tenn., with profile and plan of road, engine-plant and details of cars, etc. *Eng. News*, Jan. 7, 1888.
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- Railroading, Scientific.** By Gen. J. H. Wilson. Reviews the present position of railroading as a science and enters a plea for a good railroad school. *R. R. Gazette*, Dec. 30, 1887.
- Retaining Walls, Methods of Calculating and Designing.** By C. P. Karr. A series of articles following the methods of Dr. Weyrauch and Prof. Rankine, with additional examples from the French practice. *Building*, Dec. 17, 1887, et seq.
- Rolling Mill, Universal.** Gives description of Sacks' improved universal rolling mill, adapted to rolling double angle, star, H. T., and similar sections. *Sci. Am. Sup.*, Jan. 7, 1888.

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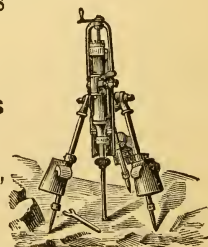
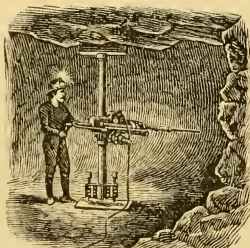
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Roof Truss, Twelfth Regiment Armory, New York. Brief description, with illustrations, of the riveted arch roof trusses of the armory of the Twelfth Regiment in New York city. *Eng. and Build. Rec.*, Jan. 7, 1888.

— A two-page plate showing details of roof truss and other ironwork of the galleries of Miscellaneous Exhibits at the Paris Exhibition of 1889. *Engineering*, Dec. 30, 1887.

Section Lining, Standard. By T. Van Vleet. Recommends the adoption of standard section to represent the conventional sections of iron, steel, etc., on all engineering drawings. Cuts show the proposed sections. *Eng. News.*, Dec. 31, 1887.

Sewage, Stone and Ault System at Rangoon Town, India. By H. F. White. A report by order of Chief Engineer of British Burma on the proposed Stone and Ault system of sewage disposal for Rangoon Town. The report is favorable, answering each objection seriatim. *Indian Engineering*, Nov. 5, 1887.

Sewerage Works, Wednesbury. Gives brief description of the works at Wednesbury. The sewage is treated with sulphate of alumina and lime. *Engineer*, Dec. 16, 1887.

Shafts, Propeller, for Marine Engines. Treats of the material from which they are manufactured, investigates the strains and proper proportions. *Mech. World*, Dec. 17, 1887.

Steam, Generation of. By G. H. Babcock. A Sibley College lecture. Treats of the generation of steam in tubular boilers. Illustrates and describes the different boilers with furnaces for burning coal, wood, gas, bagasse, etc. *Sci. Am. Sup.*, Dec. 17 and 24, 1887.

Steel, Basic Siemens Process. A paper by F. W. Harbord before the Iron and Steel Works Managers Institute, giving a description of the Basic-Siemens process of making steel. *Mech. World*, Dec. 31, 1887; *Engineering*, Dec. 16, 1887; *Am. Manuf.*, Jan. 6, 1888. A description of the Batho furnace to employ this process will be found in the same number of *Am. Manuf.*

Storage Batteries, for Electric Locomotion. A paper before the Boston meeting of the Electric Light Association, by Prof. A. Reckenzaun. Treats of the method of making batteries, their durability, &c. *Sc. Am. Supple.*, Dec. 24, 1887.

Stress, Elevation of the Limit of. A paper describing a series of experiments to determine facts in regard to the operation of the law called the elevation of the limit of stress, with miscellaneous experiments to determine physical phenomena accompanying rapid alternation of strain and rest. *Report of U. S. Board of Testing etc.*, Vol. I, 1881, pp. 107-121.

Switchback, Stampede Pass, N. P. R. R. A description with plan and profiles of the temporary switchback of the Northern Pacific Railroad over the Cascade Mountains at Stampede Pass. *R. R. Gaz.*, Dec. 23, 1887. For details of method of running trains over this switchback see *R. R. Gaz.*, Jan. 13, 1888.

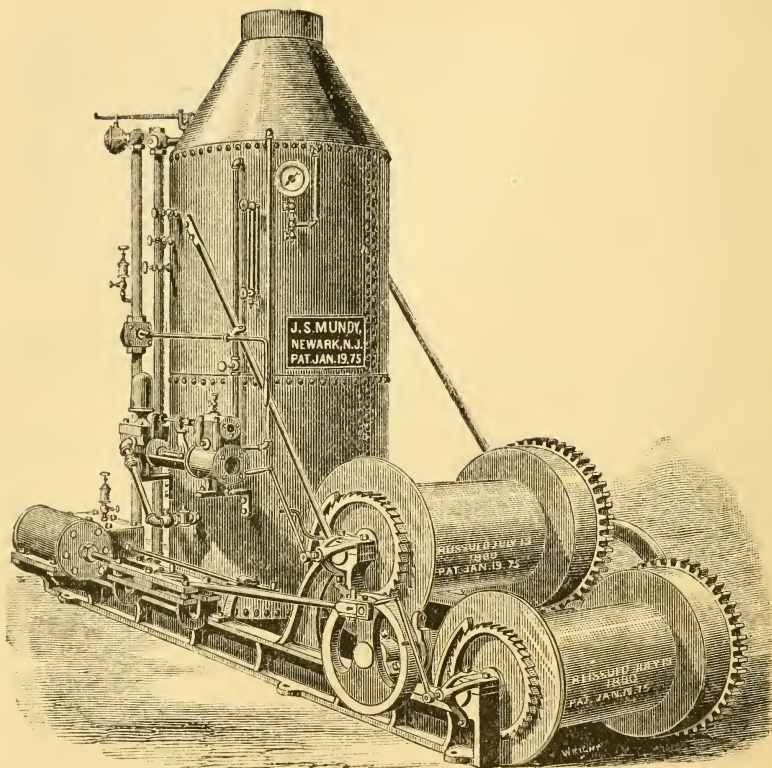
Teredo Navalis, or Ship-Worm. By G. W. R. Bayley. Gives the experience with the teredo navalis on the bridge piling and foundation of a railroad from New Orleans to Mobile. *Trans. Am. Soc. C. E.*, Vol. III., pp. 155-171.

Tramway, Electric, Bessbrook and Newry. By E. Hopkinson, before the Institute of Civil Engineers. Describes the construction and discusses the working of the Bessbrook and Newry electrical tramway, designed for freight and passenger traffic. Gives full details. Experiments show the electrical efficiency to be 72 per cent. *Engineer*, Dec. 16; *Engineering*, Dec. 9, 1887.

Trestles, Cluster Bent. By J. A. Hanlon. Gives details of a high trestle near Flushing, O., constructed on the cluster bent plan: shows plan and cross-sections. *Eng. News*, Dec. 31, 1887.

Test Pieces, Forms and Proportions of. A paper showing by experiment the correct form and proportions of test-pieces to procure correctly the tenacity, elastic limit, etc., of various metals. *Report of U. S. Board on Testing, etc.*, 1881, Vol. I., pp. 91-107.

Tests, Impact on Iron. A paper describing a series of impact tests upon various irons; with illustrated description of the hammer and method of use; tabulated details of tests and physical phenomena observed during the work. *Report of Board of U. S. Testing, etc.*, 1881, Vol. I., pp. 122-146.



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- Tubes.** *Seamless Tubes made from Solid Blanks.* A novel method of making a tube from a solid ingot by passing it between rolls, described and illustrated. *American Machinist*, Oct. 15, 1887.
- Tunnel, Vosburgh, Construction of the.** A pamphlet of 56 pages, with plates showing sections of the tunnel at various stages, systems of timbering, drilling, firing, etc., and letter-press giving details of construction, cost, etc. Address the author, L. Von Rosenberg, 35 Broadway, New York.
- Water-Mains, Draining and Filling.** By S. B. Russell, before the Engineers' Club of St. Louis. Discusses the precautions that should be taken in draining and filling water-mains. *Jour. Assoc. Eng. Soc.*, Vol. VI., 1887, pp. 298-305. *San. Engr.*, Dec. 24, 1887.
- Water-Meter, Venturi.** By Clemens Herschel, before the American Society of Civil Engineers, giving details of experiments made with a meter, embodying the property of Venturi tubes, applied to pipes from one to nine feet in diameter. Abstracted in *San. Engr.*, Dec. 24, 1887.
- Water Supply.** A paper by A. H. Dezman, attorney, before the American Water-Works Association at Minneapolis, on the legal relations existing between water companies and consumers. A valuable digest of a large number of decisions. *San. Engr.*, Dec. 31, 1887.
- *and its Development for Small Cities in the West.* By Wynkoop Kiersted. Considers the question of water supply and its development in the light of past experience. *Engr. News*, Dec. 24.
- *Village.* By S. H. Terry. Before Bolton Congress of Sanitary Institute of Great Britain. Gives examples of villages with the different systems of supply, and shows the cost of the works. *Engineering*, Dec. 2, 1887.
- Water Tank, Proper Design for a Hoop Joint of a.** By Prof. J. B. Johnson. Gives the results of tests made on the old forms, and proposes a new design. *R. R. Gaz.*, Jan. 6, 1888.
- Wire Gauges.** *Chart showing properties of all wire gauges in use.* Compiled by S. S. Wheeler. The most complete exposition of the subject yet made. *The Electrical World*, Nov. 12, 1887.
- Yachts, Racing and Cruising.** Remarks on the length, beam and sail area of racing and cruising yachts, with suggestions for defining cruisers and for regulating races. Gives tables showing leading dimensions and antics of British and American yachts. *Engineering*, Nov. 25, et seq., 1887.

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TRIPLE EXPANSION ENGINES FOR LAKE SERVICE.

BY WALTER MILLER, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.
[Read November 22, 1887.]

The writer had intended for some time to prepare a paper on the above subject, and was prevented from so doing until some data could be obtained in regard to economy, etc., and while waiting to get the desired information, the writer received imperative commands from the Chairman of Committee on Mechanical Engineering to hustle around and do something, and, as the time was short, something desperate had to be done; therefore, if this paper should lack the interesting element, you will know at whose door to lay the blame.

The past year may be regarded as a transition period in the history of the marine engine for lake service, as the high pressure triple expansion engine has now proved the successful rival of the compound engine. The object of this paper to-night is to bring before you the result of what little experience the writer has had with this new type of engine and try to describe briefly the different designs brought out, as well as that which has a direct bearing on its efficiency.

Some two years ago the writer read a paper before this Club, entitled "Compound Engines for Lake Service," and it was then stated that when the triple expansion engine with its higher steam pressure came into use (as it was certain to do) it would be still more favorable to working steam expansively, and that instead of ten or twelve expansions we would have eighteen or twenty.

Little was it expected at that time that less than one year from then the different engineering establishments of the lake marine would be actively engaged in building triple expansions for the lake service. At the time that paper was read there were no triple-expansion engines being built in this country and but very few in England or Scotland.

This fact is mentioned here to show that the engineers of the lake marine are awake to the importance of being well up to the times. The

first triple expansion engine was designed by Mr. Kirk at the engineering establishment of George Thompson & Co. near Glasgow for the steamship "Aberdeen" some three or four years ago. Since then the triple expansion engine in that country has almost superseded the double compound. In the annals of marine engineering there is no parallel to the rapidity with which these engines came into favor.

On the "Aberdeen" the saving in fuel per voyage was five hundred tons, and her carrying capacity was increased by that amount. For ease of working, smooth running and high piston speed they are not to be compared to any other class of engine built at the present time. It is only a question of time, and that very short, before the quadruple expansion engine will supersede the triple expansion engine for lake service.

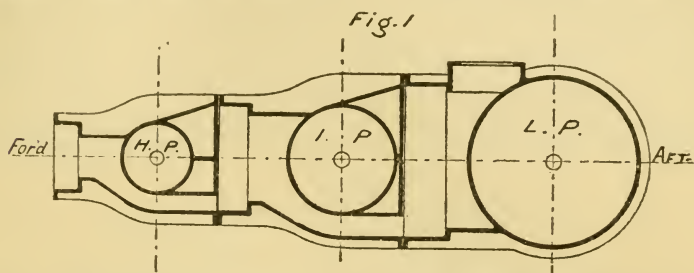
We may look for high steam pressure and little or no cut-off, but simply expand from one cylinder to the other, with cylinder ratio proportionate to decrease of temperature and increase of volume, avoiding loss by condensation and evaporation. These days one hardly gets familiar with one particular type of engine before there is another brought forward; text-books become obsolete almost before they leave the printers' hands. Imagine, if you please, Bourne's rules for diameter of piston-rod; that, is one-sixth the diameter of cylinder equals diameter of piston-rod, to apply to size of piston-rods for a triple-expansion engine, with cylinders ratio of two and one-half to one. In fact, there are but very few rules to apply to the designing of modern marine engines.

The most important change brought about by the introduction of these engines have been in the valves and valve gear. The old complicated cut-off arrangement has given place to the most simple slide valves and direct motion. With the high steam used, namely 150 pounds per square inch, all the parts of the valve gear must be well designed. Piston valves are generally used on the high pressure cylinders, single ported slide valve on the intermediate cylinder, and double ported slide valve on the low pressure cylinder. Some designers think it imperative to use piston valves on the high pressure cylinders, and piston valves have in some instances been used on all the cylinders. It has been found in practice, however, that with good hard iron in both cylinder and valve, slide valves on the high pressure cylinder work equally well and are very much cheaper and easier to repair.

Where piston valves are used on all the cylinders the clearance spaces are excessive and the steam passages are liable to be cramped, and farther, where piston valves are used throughout two valves have to be used on the low pressure cylinder, thereby complicating the valve motion. With the three cylinder, fore and aft arrangement, it has been quite a problem to design a good valve gear, and has resulted in bringing forward a number of novel devices for reversing and driving the valves. Those on the radial motion single eccentric being the more prominent, although the Joy valve and others of that class have been quite extensively used. The Joy valve gear and those of the radial motion single eccentric plan permit the cylinders to be placed fore and aft with steam chests out in front, making a very convenient engine to get at. But piston or some balance valve must be used, or else the wear will be excessive. The valve motion described above refers more particularly to

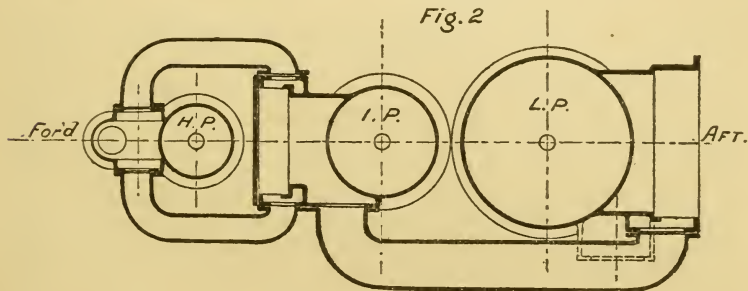
those used by Scotch and English engineers, and on nearly all of those built on the coast. But with one exception the link motion has been used on the engines for lake service. The link, when well proportioned and correctly suspended, has proven the most satisfactory arrangement yet devised to drive the valves on marine engines up to the present time.

A well known engineer on the coast after using a radial single eccentric motion on two engines declared himself still in favor of the links. It is the practice of the writer's firm, with but one exception, to place the three cylinders in line fore and aft and slide valves on all the cylinders (Fig. 1). That of the high pressure on the forward side, the intermediate



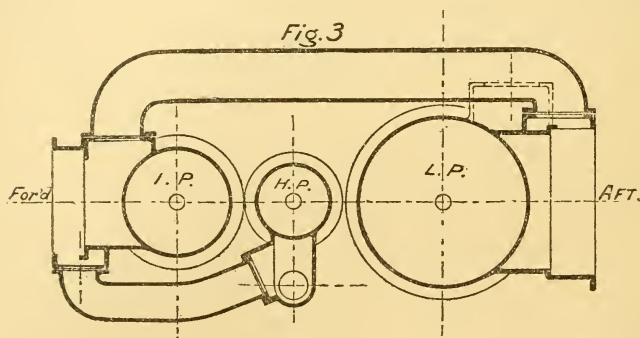
valve between the high pressure and intermediate cylinders, and the low pressure valve between the intermediate and low pressure cylinders. Single slide valve on the high pressure and intermediate cylinders and double ported slides on the low pressure, with link motion to drive all the valves. This arrangement of cylinders and valves admits of six journals in the bed plate and crank shaft in three duplicate interchangeable parts. Other builders, however, arrange the cylinders in two differ-

Fig. 2



ent ways: first, with three cylinders in line fore and aft, with piston valve on forward side of the high pressure cylinder, single slide valve on the forward side of the intermediate cylinder in separate steam chest not connected to high pressure cylinder, and double ported slide valve on after side of low pressure cylinder, with link motion to drive all the valves (Fig. 2). This arrangement admits of five journals in the bed plate and crank shaft in one or two parts. Second: The three cylinders in line fore and aft, the intermediate cylinder placed forward and slide valve and steam chest on forward side, the high pressure in the middle, with piston valve faced out in front and low pressure cylinder aft, with

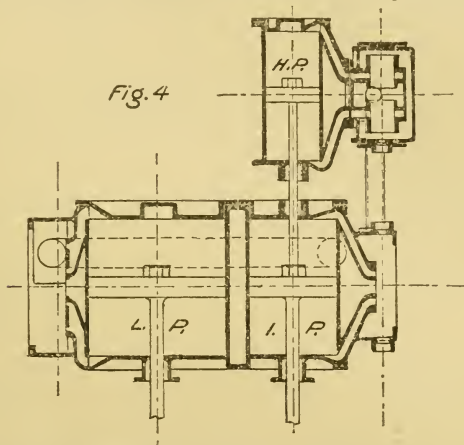
double ported slide valve and steam chest on the after side. The valves for the two outside cylinders; that is, the intermediate and low pressure, are driven with the link motion and the high pressure piston valve with Joy valve gear (Fig. 3). This arrangement of cylinders admits of but four journals in the bed plate, and crank shaft in one piece. The latter plan would seem the simplest and cheapest, but the design is open to three objections. First, there are two kinds of valve motions requiring two different motions to reverse and looks very unmechanical, to say the least, although it works well in practice. The second objection is to the journals in the bed plate, which are four in number, but are of two different lengths, and all subject to the same wear; therefore the shortest one would wear down faster than the longer one. Then, again, the two middle journals, although they are the longest, are not long enough to fill between the cranks, leaving the crank shaft unsupported close up behind the crank arms. Further, the crank shaft is built up in



one piece, with the three throws, requiring very careful work and difficult to handle. Besides, it would be very expensive to repair in case of a break down. The third objection is to the manner of passing the steam from one cylinder to the other. With the high pressure cylinder in the middle, the steam is exhausted from it to the intermediate cylinder on the forward side and exhausted from it to the low pressure cylinder, which is on the after side of the engine. This arrangement, although it works well, is like placing an engine away from the boiler and supplying it with steam through a long steam pipe. The second plan mentioned above, is, with a high pressure cylinder placed forward and piston valves on forward side, the intermediate cylinder in the middle and that of the low pressure aft, with the valve of the intermediate cylinder placed forward in a separate steam chest; between it and the high pressure cylinder also the valve of the low pressure cylinder on the after side and five journals in the bed plate with crank shaft in two parts. This plan costs more than the one with four journals in bed plate, but is open to about the same objection.

There is an unsightly array of pipes to convey the steam from one cylinder to the other, and on some engines built on this plan the arrangement of journals in bed plate is very bad. Some of the journals are extremely short, while the journal adjacent to it is more than double the length, making it impossible for them to wear down equally. The shaft,

although it is made in two parts, is not in duplicate, consequently is not interchangeable. Shafts thus made have no possible advantage except to facilitate somewhat in the building and repairs. Engines built on the first mentioned plan, that is, with the three cylinders in line fore and aft, with the high pressure forward, the steam chest on forward side, and the intermediate in the middle, with valve placed on the forward side in a separate steam chest, formed by bolting the high pressure and intermediate cylinders together: the low pressure placed aft and the valve on the forward side in a steam chest formed by bolting the intermediate and low pressure together: although the most expensive, are by far the more mechanical and conducive of the best economy. The exhaust is conveyed from one cylinder to that of its fellow in the shortest possible manner by an exhaust belt cast on the side of the cylinder almost in a straight line, and when lagged up it has a symmetrical look about it that is not seen in any of the other designs.



Access is had to the valves by covers placed on top of the steam chest. As mentioned before, there are six journals in the bed plate, all of equal length, and all things being equal, should wear down alike. The crank is in three duplicate interchangeable parts, therefore making a very simple crank to build and repair. With this same arrangement of journals and crank shafts the valve gear is brought in line with the valves without any off-sets or bent eccentric rods. What would have been a very pleasing design to the eye many times has been marred by a bent eccentric rod, aside from the mischievous way they have of dodging their work. There is another design of triple expansion engine that is considered the simplest and cheapest to build, but does not seem to take as well. That is, those that have two cylinders in line fore and aft, the intermediate and low pressure, with the high pressure placed on top of the intermediate cylinder (Fig. 4). The principle objection to this plan is that it throws too much work on one crank pin, making a very unequal strain on the crank shaft, and, you may say, all of the other working parts of the engine. There has been to the writer's knowledge but one engine built on this plan for the lake service;

although it worked well and gave every satisfaction, it did not seem to attract the attention that the others did built on the three-cylinder fore and aft plan.

Since the triple expansion engine came out, it has been the aim of designers to so proportion the cylinders that the work done in one will be about equal in each, thus equalizing the fall of temperature. In some cases the horse-power developed would not vary more than three to five horse-power in each cylinder. But this equalizing of power has been assisted by the sliding blocks in the reverse arm lengthening out or shortening the valve travel. It would seem the better way to so proportion the cylinders, valves and size of receiver space that the work done in each cylinder would be equal, and by notching up with the reverse gear vary the range of expansion, rather than trust the engineer to adjust the valve travel to equalize the work done in each cylinder. The exact ratio of cylinder is not an arbitrary matter requiring deep mathematical study. The distance from centre to centre, arrangement of valves, steam-chest and receiver spaces, as well as crank sequence, should be taken into account, as they effect the cylinder ratio very materially. Too large receiver space between cylinders would result in fall of pressure and lower temperature. Crank sequence, or order following, is best arranged by taking into account the arrangement of cylinders.

The writer's experience so far has been with the low pressure leading, intermediate following, and the high pressure last, but with the present plan of cylinders—as the receiver spaces are rather large—it would be better if the high pressure crank was leading, intermediate following and low pressure last. With the former order of following, the back pressure would be through one-sixth of the revolution, while with the latter order following the back pressure would be through one-third of the revolution; the increase of back pressure in this case would result in bringing up the initial pressure and equalizing the work done in the after cylinder. The three-throw crank shaft for the triple expansion engines built by the writer's firm are of the built-up class and require very careful and accurate work in boring, fitting and shrinking to their alignment when bolted together in place. The bed plate is first fitted with the six pairs of journal brasses and a large boring bar is run through, and all of the six journals are bored out at once; then a truing mandrel is used to scrape the journals down to a bearing. The six pieces of shaft, with couplings forged on, are all turned down to size, and the crank arms, shrunk on and keyed, are then placed in the bearings and fitted with distance pieces between the crank arm, then bolted firmly together with the eye of the crank pins in line. The same bar that is used to bore the bed plate journals is then run through, and the three pairs of crank eyes are bored at once. A portable furnace is then placed over each pair of cranks separately and the cranks brought up to the proper heat for shrinking; the furnace is then cleared away and the crank pins which have been turned down to the finished size are then shoved in place and left to cool. Each part of the crank shaft is then put in the lathe and about one sixty-fourth of an inch turned off the journals and the couplings faced up. The holes for the coupling bolts are drilled by templet and the bolt holes are reamed

after the cranks are in place. Each part of the crank is in duplicate and will interchange, thus lessening the delay in case of a broken crank. The increased steam pressure carried has resulted in the abandonment of the old return tubular fire-box boiler, so long in vogue for the lake service. With such large crown sheets and flat stayed surfaces, it was impracticable to continue their use and has led to the adoption of the boiler which is commonly called the Scotch boiler, with circular furnaces and return tubes. The furnaces are either corrugated or else flanged in short lengths with rings between the flanges. Boilers on this plan are now being made for the lake service 14 feet in diameter by 12 feet long, with steel shell plates $1\frac{5}{8}$ inch thick, to carry 160 pounds of steam per square inch. The shell plates are all drilled and double riveted by hydraulic riveters, as it would be almost impossible to make these boilers tight by hand riveting. Heavy machinery for riveting, bending, flanging and drilling these plates, for the building of these boilers, have had to be added to the boiler building plants on a scale little thought of two years ago. As yet nothing has been mentioned as regards the economy of the triple expansion engine for lake service. As was intimated at the beginning of this paper, the writer had been waiting for some data to compare with the compound engine, therefore can only say that they have shown a very marked economy, but how much am not able to give any figures. When lake freights are booming, like the season just closing, twenty or thirty tons of coal a trip is not much of an object, and vessels that can carry and have plenty of power to push them through the water are made to go, but for smooth working, ease of turning and high piston speed they have been a success.

DISCUSSION.

Mr. Whitelaw: In the August number of "The Century," Edward Atkinson makes the statement that "a cube of coal which would pass through the rim of a quarter of a dollar, when used in connection with the compound engine, will drive a ton of freight and its proportion of the steamship two miles on its way from the producer to the consumer. By the invention of the triple compound, one-fourth even of this fuel has been saved."

Mr. John Walker: With regard to piston valves, the piston valve may be very good in some respects, but there is one great objection to it. If there is any water in the cylinder, it cannot be lifted from its seat to let the water out, and accidents may be caused, while the slide valve will raise from its seat if there is undue pressure in the cylinder. The Joy valve is admitted to be one of the greatest improvements of the age. I know Mr. Joy personally. He is a fine mechanic. After examination of these three diagrams, I must give my vote in favor of the first. The fact of the crank shaft being made in three duplicate parts is a very commendable feature. The statement about the cube of coal which would pass through the rim of a twenty-five cent piece is no doubt correct. It is astonishing when we consider what a small cube of coal will do, or what a volume of steam is generated from a small amount of water. I think the economy of the compound engines, as well as the

triple engines, is largely dependent upon the draughtsman. A compound engine may be spoiled in the draughting.

Mr. Walter Miller: There was a discussion on the subject of comparative economy of the triple expansion engines in England recently. Various reasons were given for the saving in fuel over that of the compound engines. One said that it was due to the higher steam carried; another gave it as his opinion that it was due to the method of working the steam in the cylinders, but none of the opinions appeared satisfactory to all. One of the engineers present said that he did not care where the economy was effected, as long as the shipowners knew that they could make a certain voyage and back with a saving of coal, that was enough.

I usually work from the larger cylinder, taking the number of expansions to get the mean effective pressure; then after the size of the large cylinder is determined, the size of the other two is obtained by the ratio of the expansions you want to use, usually two and one-half times. The principal point of economy in those engines is in the method of expanding the steam; that is, not expanding it all in one cylinder, thus exposing the cylinder to the extremes of temperature due to the initial and terminal pressure. My first experience was with the condensing engines. When the compounds were coming into use, engineers said they could make the condensing engines just as economical as the compound. All they had to do was to carry higher steam and cut off shorter, and get the same number of expansions that we did in the compound. We did carry higher steam, increased it from 40 to 70 pounds, but there was little or no saving. Then it became evident that they were carrying too high steam. The first incoming steam was condensed on the walls of the cold cylinder, and as it went to the end of the stroke, re-evaporation took place directly the exhaust opened and the whole was swept into the condenser and lost. When we come to the compound and triple expansion engines the case is different. The steam is allowed to follow the piston faster in the stroke, therefore the extremes of temperature at opposite ends of the cylinder are less, and the condensation and re-evaporation that may take place are utilized in the cylinder or cylinders following. With regard to the piston valve, the matter of its lifting off the seat requires little attention, from the fact that large relief valves are used on the cylinder. Diagram No. 4 has a piston valve on the high-pressure cylinder, and it gave excellent results. The Joy valve gear is certainly a good one, and gives a more accurate distribution of steam than any valve gear used up to the present time. The objection to it is that the valve must have some relief. It is necessary to use piston valves. The crank arms are bored out to size, and the crank shafts turned down to a shrinking fit. The crank arms and shaft are key seated, and the arms shrunk on and keyed.

Mr. Deering: What is the pressure on the second cylinder?

Mr. Miller: With 150 pounds on the initial, it would enter the second cylinder anywhere from 40 to 60 and 80 pounds.

Mr. Walker: If the pressure is 100 pounds in the first cylinder and occupies twice the space in the next cylinder, there will be 50 pounds of

increased area in the second cylinder. Of course there is loss in passing from one to the other.

Mr. Miller: In regard to the back pressure line, it is a puzzling question to most engineers what deduction to make. The back pressure line is merely the initial pressure of the cylinder following it. If we were to take into account the back pressure on the high pressure cylinder and apply it to the cylinder following it, there would be a positive gain in proportion to the ratio of cylinders; that is, if we had a back pressure of 20 pounds on the high pressure cylinder and the cylinder ratio was two and a half to one, then our 20 pounds back pressure would be equivalent to an initial pressure of 50 pounds on the cylinder following, but the volume is increased in the same ratio directly the piston begins to move; therefore we have only a uniform initial pressure throughout the stroke, minus loss in receiver space as undue back pressure from contracted steam passages. A short time ago a gentleman said to me, in thinking about the three cylinder engines, I cannot see where there is any benefit; after you deduct the back pressure, there is nothing gained. I advised him not to trouble himself as to where the gain was, as in all probability he would never discover it.

THE VOLT, THE OHM AND THE AMPERE.

BY FRANCIS E. NIPHER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read January 4, 1888.]

There are many engineers who do not understand the nature of the investigations which have led to the adoption of the familiar units named above, and who do not find in works accessible to them a sufficiently clear discussion to enable them to understand, for instance, how the electrical resistance of a piece of wire like the one which I hold in my hand can be 6,200 miles per second.

The experiments upon which the determination of these units was based were made with exactness by a committee of the British Association.* The equations for the reduction of the observations were written by Prof. Maxwell. These equations take into account many corrections that must be made, and do not well serve to bring out their full meaning to one not conversant with the subject.

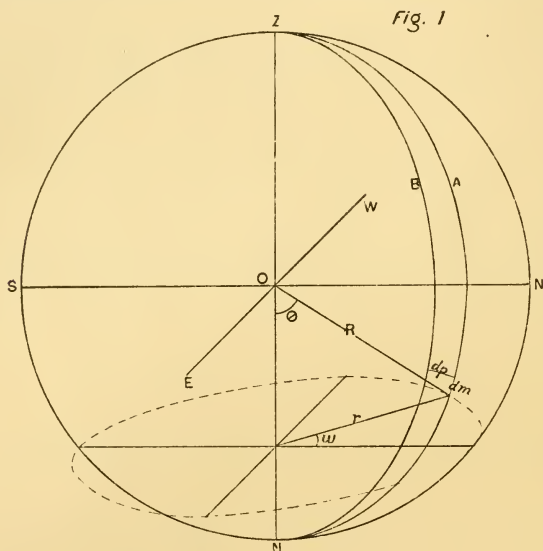
A simpler form of apparatus, such as the one represented in diagram in Fig. 1, although impracticable for experimental determinations, will serve a much better purpose for an exposition of the subject.

Let $ZN'NS$ be a circular closed wire, revolving around a vertical axis ZN' in a field of magnetic force of strength H . The value H is determined in units which depend only on the centimeter the gramme and the second, by means of a magnetometer. The strength of field is also

* Reports of Electrical Standards, p. 96.

called the number of lines of force per square centimeter, and in Fig. 1 the lines are supposed to be parallel to the line NS . On the plane $ZWN'E$, the number of lines to the square centimeter will be everywhere the same, and equal to H .

At any instant let the plane of the coil be represented by ZAN' , mak-



ing an angle w with the meridian plane. During an interval dt , the plane of the coil will sweep through an angle dw , the new position being ZBN' .

The area of an element of the surface of the generated sphere will be

$$ds = dp \cdot dm$$

where dm is an element of one of the meridian circles and dp is the arc of the horizontal parallel at the same point, subtending the angle dw .

Let θ = angle between the vertical radius ON' , and the radius drawn to the element ds , R' being this radius and r the radius of a horizontal parallel cutting ds .

Then

$$dp = r dw = R' \sin \theta dw$$

$$dm = R' d\theta$$

$$ds = dm dp = R'^2 \sin \theta d\theta dw$$

Let ds' , dm' and dp' be the projections of ds , dm , and dp on the plane $ZWN'E$.

$$dp' = dp \cos w$$

$$dm' = dm \sin \theta$$

$$ds' = dp' dm' = dp dm \sin \theta \cos w$$

$$= R'^2 \sin^2 \theta d\theta \cos w dw$$

Keeping w constant, if we integrate the last expression between the

the limits 0° and 360° , we shall get the area of the projection of the spherical sector intercepted between the two planes, upon the plane $ZWN'E$.

$$\int_0^{2\pi} \sin^2 \theta \, d\theta = \left[\frac{1}{2} \theta - \frac{1}{4} \sin 2\theta \right]_0^{2\pi} = \pi$$

Calling this sector-projection S'

$$S' = \pi R'^2 \cos w \, d w.$$

The electromotive force of the wire being the number of lines of force cut per second, we have

$$E = \frac{SH}{dt} = \pi R'^2 H \frac{dw}{dt} \cos w$$

If $A = \pi R'^2$ and n = the number of revolutions per second, then the angular velocity $\frac{dw}{dt} = 2\pi n$

Then the value of E is

$$E = 2\pi n A H \cos w \quad (1)$$

The average cosine being $\frac{2}{\pi}$, the average electromotive force in

$$E = 4\pi n A H. \quad (2)$$

When the plane of the wire is at right angles to NS , the number of lines inclosed by the wire is AH . After a quarter revolution the number inclosed is 0. Hence AH lines are cut during each quarter revolution, and $4\pi n AH$ will represent the number of lines cut per second.

In (2) the area being in square centimetres, and H being measured also in C. G. S. units, it is evident that E is expressed in terms of the same units.

If now the coil were broken, say at N , and connected with commutator bars and brushes so that this electromotive force could be compared with that of a Daniell cell, it would be found that when the E. M. F. of the coil and cell balance, the value of E as calculated by (2) would be

$$E = 107000000.$$

This number is too large to be convenient, and so a practical unit 10^8 times as large is selected, and it is called a volt. In volts, then, the E. M. F. of a Daniell cell is 1.07.

It will be understood that the single coil could not be given a speed which would produce an E. M. F. of one volt. For the real determination a coil of many turns would be required.

By Ohm's law and equation (1) the current at any instant during the revolution is

$$C = \frac{E}{R} = \frac{2\pi n A H}{R} \cos w \quad (3)$$

where R is the coil resistance.

A small magnet is suspended at the centre of the coil, upon a silk fibre which passes up through the hollow axis at Z . This magnet is deflected by the action of the coil, and comes to rest when the turning moment due to the earth's field balances that due to the coil.

The force of the field on one pole of the magnet is Hm , where m is the strength of the pole. The component of this force resolved at right angles to the magnet is $Hm \sin \alpha$, where α is the angle of the magnet axis with the magnetic meridian.

To find the force of the current upon the same pole, consider the effect of an element of a current having any form upon a pole m . In Fig. 2 AB is the conductor carrying a current C . The force of any element dl of this current upon the pole m is

$$df = k \frac{C m dl}{R'^2} \cos \beta.$$

Where K is a constant, R' is the distance between the element and the pole and β is the angle between the lines drawn from m to the element, and from m at right angles to the tangent of the conductor at the element.

To get the effect of a finite portion of the circuit this expression must be integrated along the wire between the limits assigned to l , which can be done whenever the geometry of the circuit is known. In the case of the circular wire with the poles at the centre, $\cos \beta = 1$ for all parts of circuit, and the expression is therefore merely to be integrated in l . The force on one pole is therefore

$$f = K \frac{Cm \times 2\pi R'}{R'^2}$$

If now C be made unity when the current is so adjusted that the action of a centimetre of wire, every part of which is a centimetre from a unit pole and which is traversed by this current, acts upon the pole with a force equal to one dyne, the constant K becomes unity. The value of C is hereafter therefore to be understood as expressed in the above chosen centimetre-gramme-second unit.

Replacing C by its value, as previously determined (3)

$$f = \frac{4\pi^2 A H n m}{R R'} \cos w$$

This being the force at right angles to the coil, the component at right angles to the needle will be

$$f' = \frac{4\pi^2 A H n m}{R R'} \cos w \cos (\alpha - w).$$

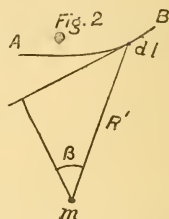
This force will fluctuate during a revolution, being zero when w is 90° or 270° , when the coil is not cutting lines of force (the value of E in (1) becoming zero), and when $\alpha - w = 90^\circ$ or 270° , when the force of the coil is longitudinal with respect to the needle, the needle being at right angles to the coil. For intermediate positions, as is well known, the sign of the turning moment on the needle will remain unchanged, since the reversals of the current are simultaneous with reversals of position of the wire with respect to the magnet.

Moreover, when the experiment is made with a speed of ten revolutions per second, the needle appears perfectly steady under telescopic observation with a reflecting scale, the needle being in the form of a small sphere of steel.

It becomes necessary then to find the average value of the expression $\cos w \cos (\alpha - w)$

$$= \cos \alpha (\cos^2 w + \tan \alpha \sin w \cos w),$$

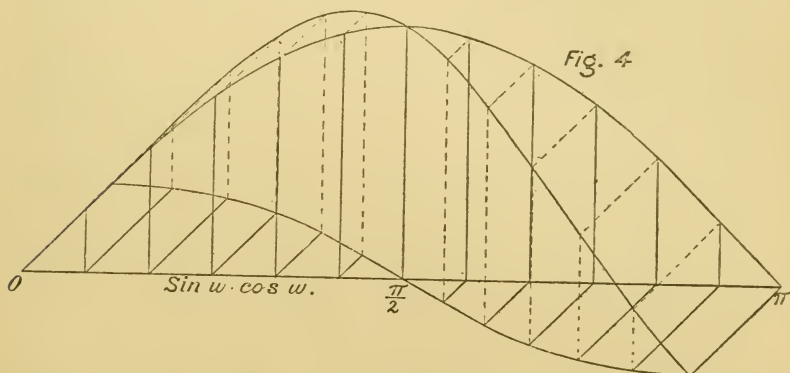
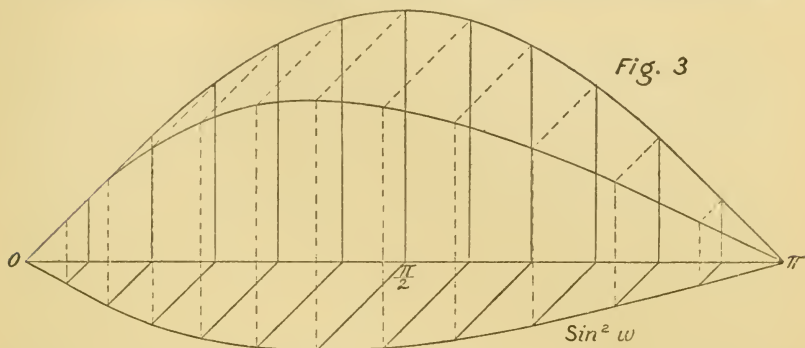
where α may be considered constant. To do this the expression within



the parenthesis must be multiplied by dw and integrated between the limits 0° and 90° , dividing the integral by the arc of 90° . Calling the average value of the parenthesis S , it is

$$S = \left[\int_0^{\frac{\pi}{2}} \cos^2 w \, dw + \tan \alpha \int_0^{\frac{\pi}{2}} \sin w \cos w \, dw \right] \frac{2}{\pi}$$

The values of these two integrals are well known, and are represented in Figs. 3 and 4, which are obtained by laying off \sin^2 , and $\cos \times \sin$



along the rectified arc between 0 and 180° .* The average value sought is simply the sum of the average sections of these two solids, the latter being multiplied by a constant $\tan \alpha$. Performing the integrations, and calling f'' the average value of f' ,

$$f'' = \frac{4 \pi^2 m n \Delta H}{R R'} \cos \alpha \left(\frac{1}{2} + \frac{\tan \alpha}{\pi} \right).$$

* It will be seen that in case of the solid represented by $\int \sin w \cos w \, dw$, the edge of the solid diagonally opposite the axis of arc is a helix, which makes one turn for every 360° of change in w . The sine and cosine curves are, of course, projections of that helix on any planes at right angles to each other, the line of intersection of the two planes being parallel to the axis of the helix. Revolving either the helix or the two planes about the axis of the helix will, of course, change the phase of the projection curves.

For equilibrium of the needle this must equal $H m \sin \alpha$. Hence remembering that $A = \pi R'^2$

$$R = 2\pi^2 R' (2 + \pi \cot \alpha).$$

The average distance of the elements of the wire from the axis of revolution is $\frac{2}{\pi} R'$. The average circumference described by these elements is therefore $4 R'$. Hence, the average velocity of the wire in space is $4 n R' = v$.

Substituting this value in the above equation, we have finally

$$R = \frac{\pi^2}{2} (2 + \pi \cot \alpha) v.$$

This value of R is therefore expressed in centimetres per second. If a wire having a resistance such as we call one ohm could be revolved in the manner here discussed, so as to produce a measurable deviation, the value of R would be found to be 1000000000 centimetres per second. The numbers expressing resistances of such pieces of wire as are ordinarily used are thus seen to be very large numbers. For practical purposes a new unit 10^9 times as large as the C. G. S. unit is called the ohm.

Since by Ohm's law

$$C = \frac{E}{R}$$

it is evident that since both E and R have been determined in C. G. S. units, the same can be said of C . Since, furthermore, the practical unit E or volt is 10^8 C. G. S. units, and the ohm is 10^9 , it is evident that the practical unit of current to be chosen in order to avoid the introduction of a constant into the last equation must be 10^{-1} C. G. S. unit. This practical unit is called the ampère. Ten ampères thus make a C. G. S. unit. These changes from C. G. S. units to practical units may be said to be brought about by the adoption of 10^9 centimetres, or an earth quadrant as a new (but not very practical) unit of length, and 10^{-11} gramme as the new unit of mass, the unit of time remaining the second.

This change is the practical solution of the difficulty, that, measured in C. G. S. units, resistances and potentials (electromotive force) are represented by very large numbers, and quantities and capacities by very small fractions.

The labors of the British Association Committee with the revolving coil resulted in placing upon the market a standard ohm, which has taken the name of the B. A. ohm. Later investigations seem to indicate that the B. A. ohm is about 0.9864 of the true ohm— 10^9 C. G. S. units—and that the best value for the ohm will be the resistance of a column of pure mercury at 0 degree C, whose section is one square millimetre and 106.278 centimetres in length.

The Paris Congress of 1884 adopted for ten years a column of mercury as above, and 106 cm. in length as a unit of resistance, and called it the *legal ohm*. It is expected that before 1894 the slight difference between the legal ohm and 109 C. G. S. units will be determined with sufficient precision for all ordinary purposes, and that the legal ohm will then receive the slight adjustment needed to make it agree with the theoretical

value. The legal ohm is 1.0112 B. A. ohms. The *legal volt* is the electromotive force which will maintain a current of an ampère through a conductor whose resistance is one legal ohm.

The *legal ampère* is thus 10^{-1} C. G. S. units of current.'

CONTOUR LINES.

BY BERNHARD FEIND, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.
[Read December, 1887.]

The modest paper I am about to offer treats of a branch of topographical work which, I am sure, is not wholly devoid of interest to the profession at large, and which is likely to prove, at one time or another, very attractive to individual members. I beg leave to submit to you for consideration and discussion, if you should deem the latter worth your while, some views on the subject of contour lines.

A contour line I take to be the outline of a horizontal section through a portion of the earth's crust, in contra-distinction to a profile which is the outline of a vertical section through a portion of the earth's crust, or by expansion of the term, this vertical section in its entirety. A contour plan or map is obtained by projecting the outlines of a series of these horizontal sections to a common datum section. These so-called horizontal sections are the surfaces of ellipsoids, parallel to the theoretical surface of the globe, and portions of them may be treated as spherical or plane surfaces, according to extent. All points of the same contour line represent, *co ipso*, the same level. An ideal contour plan would be that which would enable us to obtain a perfect model of that portion of the earth's crust which is under treatment. The term "perfection" is taken in its boldest sense here.

Let us imagine that we might obtain this perfect model by molding slabs of some plastic material, each of a thickness representing the vertical distance between two neighboring contour sections, the edge of its top surface representing the upper contour line and the edge of its bottom surface representing the lower contour line; these slabs to be joined in their order. Supposing the contour lines to be perfectly true to nature, our model would be a perfect one only if the slope between the two sections were also, in its every part, perfectly true to nature.

If the surface of the globe consisted of plane polygons, no matter how irregular, we might obtain our perfect model by taking a true contour section at every corner of the configuration. The vertical distances between these sections would be measurable quantities. But nature abhors straight lines and plane surfaces, and in order to obtain our perfect model the distance between contour sections would need to be infinitesimally small. In this case we should be justified in considering the slope between two sections as a chain of rectangles. In other words, an ideal contour plan would be so constituted that a true profile imagined to be taken at right angles to each of a series of contour lines would result in a straight line between each two neighboring contour lines, both in horizontal and vertical projection. How closely we should aim in practice

to approach this ideal depends entirely on the character of the information which we desire to derive from the contour plan.

Assuming the possibility of obtaining a perfectly true contour line at a given level, the vertical distance between two contour sections is the sole factor determining the degree of approximation to truth in the strip of surface bounded by them. But in a great majority of cases it would not even be good sense to take great pains to procure at given levels a highly accurate outline, the benefits of which might be neutralized by the unavoidable infringements on truth of surface, due to the limitations in choice of vertical distance.

The two factors, vertical distance and degree of accuracy in outlining, ought to be adjusted to each other; and vertical distance, being easy of definition, will be the leading factor. In its turn the efficacy of this leading factor is determined by the scale of the map, excluding exceptional conditions as to skill, time and tools employed in compiling. When the scale of the map is determined before-hand, as it frequently is where contour lines are more or less important adjuncts of a plan only, we may, from a general knowledge of the steeper slopes intended to show well on the plan, infer at once the minimum of vertical distance admissible in order to make the plan clearly legible. For instance, in a contour plan of 1000 feet to the inch, in which slopes of 1 to 5 are expected to show well, we should not make the minimum of vertical distances smaller than $\frac{1}{50} \times 1000 \times \frac{1}{5} = 4$ feet, in which case the 1 to 5 slopes are shown by lines $\frac{1}{50}$ of an inch apart. If this minimum is not chosen as standard vertical distance, some product ought to be of which this minimum is one factor, and some power of digit 2 the other factor, so that we may arrive at the minimum by continued bisecting. Even thus the most characteristic contour lines would often fail to appear, and these might properly be interpolated in some striking manner without regard to their elevation.

On the other hand, of course, the scale of the map may be adjusted to a given minimum and standard of vertical distance demanded by the character of the ground, considered in connection with the uses to which we intend to put the finished plan.

And now we find ourselves in the field. Our task may be a reconnaissance of an unexplored country for the purposes of science, war, or any of the manifold means of peaceful intercourse of man; or we may be in search of the niceties of surface formation for the purpose of adjusting details of an engineering project; we may have in view a standard vertical distance of 100 feet or of one-half of a foot—the principle remains the same, namely, to furnish a reproduction of outlines of imaginary horizontal sections through the earth's crust. A mere routine of doing the business would be to trace these imaginary lines directly on the surface of the earth, to crawl along in the capricious path of the contour line with plane table and level. That kind of thing has been done extensively by officers of staff departments of large standing armies during the tedious times of peace. The civil engineer will not, as a rule, adopt methods like this; in the present case he will, from the very outset of his task, rely on the judgment of a keen and trained eye for giving aim and aid to measurements by instrument. The eye has to determine first what work the instrument is to do, and afterwards should

connect the scattered elements of information gathered by the instrument. On the other hand, the work of the eye is supported and verified by that of the instrument.

What instruments should be chosen for the work and how they should be handled will depend mainly on the proposed standard vertical distance as the best exponent of what is expected from the plan. We have aneroid and mercurial barometers, vertical circles and levels of different sorts and grades to determine elevations; we have transits, compasses, sextants for measuring angles, and chains, tapes, stadia attachments to transits, odometers, pedometers, and our own sturdy, even-paced limbs for measuring distances, by which angles and distances we determine the location of points of known elevation. A very simple and efficient combination of instruments for the latter purpose in small scale contour line work, especially where the lines of our admirable land system are traceable in the field, will be found to consist of pocket sextant and pedometer. An Y or a dumpy level of average grade can hardly be dispensed with in any but the roughest sort of contour work. I take it. No more on this phase of the question at present. As to the work of the eye, the *plastic conception* of the task, as outlined at the commencement of this paper, seems almost indispensable. We must gaze into the face of nature, as it were; gaze at morning, noon and night; in the shadow, in the light; from the depth, from the height; gaze long and fondly; conjure up before our mental vision a living image of that face, until we feel impelled to seize on a lump of clay and knead it into a likeness of that face. True, that face often seems at first so very flat and inane that we find it very difficult to become enthusiastic; but when we shall have supplemented our failing judgment by measurements, we shall be surprised to find the face very interesting after all. Those imaginary lines of the face, the contour lines which we are in search of, sometimes are very difficult of being traced by the eye directly; in fact, they often, when thus pursued, prove to be *ignes fatui*, leading us into the mire of perplexity. But there are real lines in the face, the grand lines of divide and thalweg with all their ramifications. These are often exceedingly well defined by marks of running or stationary water, by silhouette against sky or suitable background; they further have this advantage, for our purposes, that they intersect the contour lines in the most important and, generally, most prominent points of the latter and at right angles exclusively. To the development of these lines, therefore, the principal care of eye and instrument ought to be devoted. The only other element of land surface besides divide and thalweg is slope. Of this fine silhouettes are often caught and good impressions gained in a variety of other ways.

The plastic conception of our task, the endeavor to form, before our mind's eyes, a plastic image of the crust of the earth on which contour lines and lines of divide, thalweg and slope are expressively traced, is greatly facilitated by a habit of taking note of any object striking or odd in form or color, however trifling or in itself foreign to our task. The remembrance of such an object in its natural surroundings will tend to make the image before our mind's eyes yet more vividly distinct. That vivid image present before us, the sketches and notes taken while form-

ing that image and the plotted field notes of the instrumental work will enable us to prepare the first draught of the contour plan in our quarters or our improvised office in the field. The first draft is then compared with nature, and altered or improved upon until it meets our ideas of approximation to the true or ideal contour plan described above.

To sum up and to emphasize, the principles of contouring advocated in this paper are the following ones : Cultivate the faculty of plastic conception of your task. Put the instrumental work where it will do the most good ; that is to say, chiefly on the divides and thalwegs, on those parts of slopes contiguous to either, on places of pronounced breaks in slopes, and on all those places where your judgment fails you. Prepare the first draught of the contour plan in the field. Prepare it yourself, and do it quickly, before your impressions fade. Compare the draught with nature, and verify it as to needed approximation to truth before you leave the field.

Properly compiled, contour plans are certainly of great value to geologists and meteorologists, to military engineers, and to the majority of civil engineers. Intelligently prepared, contour plans are comparatively inexpensive, not to say very cheap, and besides giving the most tangible representation of the conditions of surface drainage, in a great many instances may be made to do as good service, if not better service, for the calculation of quantities of excavation and embankment than the usual cross-sectioning. On this last subject a nice little paper might be written.

TESTING THE STRENGTH OF ENGINEERING MATERIALS.

BY J. B. JOHNSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read November 16, 1887.]

All engineering structures require three lines of investigation for their complete design, viz.: A study of the maximum external loads or forces likely to come upon the structure, a proper mathematical analysis of these forces to determine the maximum stresses caused in all parts of the design, and finally the strength and dimensions of the members or parts to safely carry the stresses. In the entire investigation the two controlling objects are, safety and economy. Since these two objects are necessarily antagonistic, the engineer is in constant danger of allowing himself to be unduly influenced by the one or the other. Evidently the maximum economy with sufficient safety is only attainable when all the facts of this triple problem are fully known. It is safe to say that all the facts are never known in any one of these departments of external forces, internal stresses, or strength of members or parts. But it is evident that the more nearly we can come to knowing the facts, the more successfully can we satisfy the conditions of safety and economy.

The first two departments of the problem, those of the outer forces and the internal stresses, have been studied with such completeness and detail as to largely remove them from the field of further inquiry. In many cases there is still great uncertainty as to what assumptions should be made concerning the outer forces coming upon

some structures, but when these are given the internal stresses resulting therefrom is usually a matter of mathematics simply, and the mathematical sciences have always led all others. Engineers have ceased to take much interest in methods of analysis, whether analytical or graphical, for finding stress in structures, since every polytechnic school boy is now thoroughly instructed in this kind of knowledge. But when these stresses are found, the question of what is the most economical material, and the best distribution of the same, will always have great interest to engineers, since it will always remain largely an unknown quantity. It is here that the factor of ignorance, called a factor of safety, mostly comes in, and it is to this part of the general problem of designing a structure that we shall devote our attention.

The proper disposition of material to resist various kinds of stresses is wholly dependent on the strength of the material to resist such stresses. The strength of a given material to resist a given stress is best found by experimental tests. It is often found by what may be called the structural test; that is, building a structure that falls down under certain computable loads, and then finding what the strength of the material was from its failure.

This is evidently the poorest and most expensive way in the world for obtaining this kind of information; but, strange to say, it is the way in which most of the world's knowledge on this subject has been gained, and this is still the only way the self-styled "practical man" has for obtaining his knowledge in all three of the departments of designing.

With the wonderful development of all kinds of engineering operations which followed the application of steam on a large scale in the arts began systematic experiments in England on the strength of engineering materials. The demand for such investigation has steadily increased, until now large testing machines are found in every large manufacturing centre, as well as in all the better class of engineering schools, and all engineering students are taught to use these machines in original investigations for themselves. The literature of engineering is now largely composed of accounts of tests and discussions of the same, and engineers evidently feel that the greatest immediate progress in their profession is to be made in this direction. From the nature of the case also it is not probable that this growing disposition to test all materials used in important work will ever be satisfied, and the practice be abandoned. With greater competition between manufacturers comes a greater desire to cheapen the cost of production by lowering the grade of the product, and the only remedy the engineer has, or can have, is the ever present testing machine and its indisputable results. These will silence captious remonstrance when nothing else will. It is at once the engineer's guide to a proper design, and his guard against inferior execution.

I will now epitomize the present state of knowledge in regard to certain materials, and indicate how tests can be made useful in designing.

THE FATIGUE OF METALS.

Elaborate experiments in Germany and elsewhere have shown that

the ultimate strength of metal from a single test is no indication of its ability to resist repeated stresses.

If f = initial unit strength ;

p_1 = greatest unit load which may be repeated an unlimited number of times ;

p_2 = greatest unit stress which can be reversed an unlimited number of times ;

then we may call

f the Initial Strength ;

p_1 the Repetition Limit ;

p_2 the Reversal Limit.

That is to say, p_1 is the greatest unit stress which can be wholly removed an unlimited number of times, while p_2 is the greatest unit load which can alternate from tension to compression an unlimited number of times. Both p_1 and p_2 are below the elastic limits for wrought iron, p_1 being about 21,000 pounds per square inch and p_2 about 16,000 pounds per square inch. The ultimate strength may be put at 50,000 pounds, and the elastic limit at 30,000 pounds per square inch.

But in practice the maximum load is seldom wholly removed, and often the reversed stresses are not equal, so that in general we may say that we have a maximum unit stress m , and a minimum unit stress n . This minimum stress may or may not be of the same kind (tension or compression) as the maximum stress. For these general cases it is desirable to know what the values of m and n may be for any material.

In Fig. 1 the relation of these limiting and working stresses is shown graphically. Distance along the line represents stress per square inch, measured either way from o as an origin.

Thus: $of = f$ = Initial strength.

$op_1 = p_1$ = Repetition limit.

$op_2 = p_2$ = Reversal limit.

The stress of represents the strength of the material from a single test. The point (e. l.) is the elastic limit from a single test, but it plays no important part in this discussion. The stress op_1 may be put wholly on and off an unlimited number of times, and the stress op_2 may be changed to op'_2 an unlimited number of times.

If all the stress is not removed each time, but only a part of it, then the maximum stress m may be greater than p_1 , so that if a certain portion of om , represented by on be left on permanently, then m will lie somewhere in the field p_1f , and the greater is the ratio of the fixed to the varying stress, the more

nearly will m approach f . Similarly if only a part of the stress is repeated with the opposite sign, then the greater of the two stresses, m , will lie somewhere in the field p_1p_2 , and the less, n , will lie between o and p'_2 , and the more nearly n is numerically equal to m , the more nearly will m approach to p_2 . Thus we may say that the maximum stress, m , will always be p_1 plus a portion of p_1f when n is of the same kind of

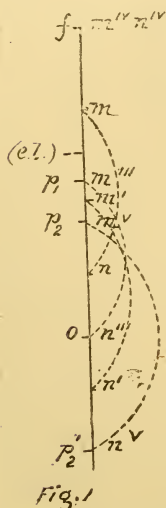


Fig. 1

stress, and minus a portion of $p_1 p_2$ when n is of the opposite kind of stress.

It has been found by experiment that the following is approximately true: *The maximum stress is equal to the repetition stress p_1 plus or minus such a part of the adjacent field as the minimum stress is a part of the maximum stress.*

$$\text{Or, } m = p_1 + \frac{n}{m}(f - p_1) \text{ for repeated stresses.} \quad (1)$$

$$\text{And } m = p_1 - \frac{n}{m}(p_1 - p_2) \text{ for reversed stresses.} \quad (2)$$

These are the formulæ to use for determining the breaking stress m when the smaller stress n is known, and when these stresses succeed each other an unlimited number of times.

This is also shown in Fig. 1.

Thus when n lies above o , m is above p_1 .

“ n lies below o , m is below p_1 .

“ n is at o , m is at p_1 .

“ n is at $p'_2 (= -p_2)$, m is at p_2 .

“ n is at m (static load), m is at f .

Evidently $m - n$ is always the portion of the stress removed each time, corresponding to the movable load on bridges.

Formula (1) is named after Launhardt, and formula (2) after Weyrauch.

For every variation of stress there is a corresponding distortion, and the product of the mean value of the variable stress into the distortion is the work, in foot-pounds, done on the material in distorting it. When the stress is partly or wholly removed the member recovers a corresponding portion of its distortion, and this is work done by the member against the external forces. Now it is this *work* which *wears out* or *fatigues* the material. A given material can recover its length an infinite number of times if the work demanded each time be not too great, and hence it is capable of doing an infinite amount of work if done in sufficiently small amounts. If too much be required at any one time, however, then it wears out, or becomes fatigued, and finally breaks down, very much the same as an overworked muscle.

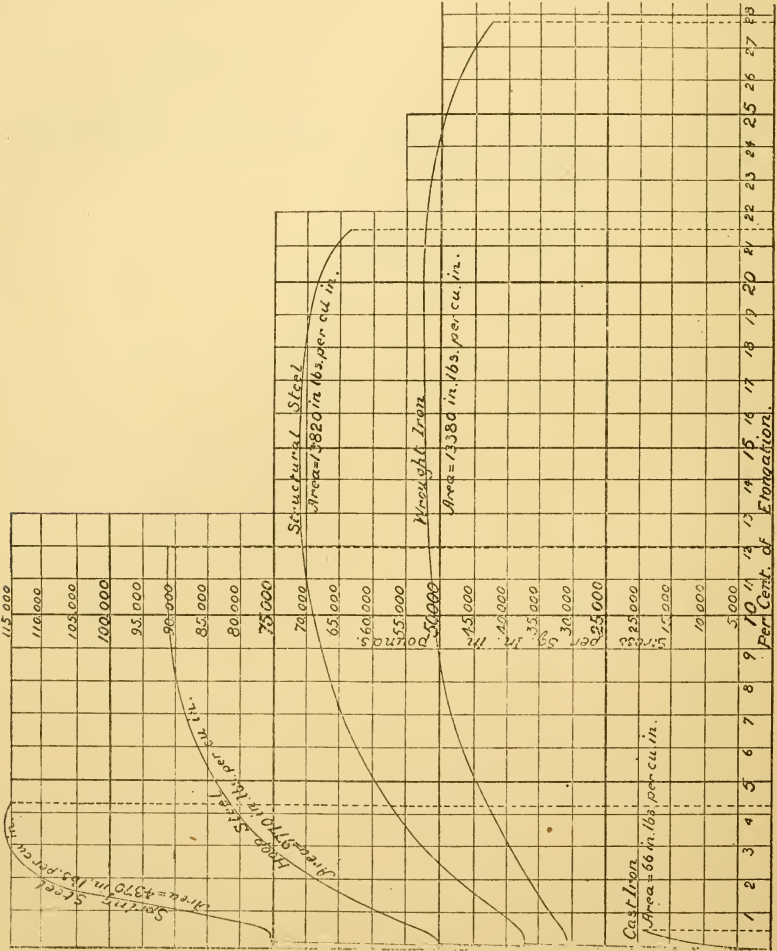
Now the amount of work done at any one time has been shown to be the mean stress into the distortion. In order to keep this maximum single effort a constant, it is evident that as the mean stress increases, the distortion must diminish. In other words, as the maximum load increases, the *variation in load* ($m - n$), must decrease. But for m increasing, $m - n$ can decrease only by the more rapid increase in n ; therefore, it is only by increasing the static load n , that the total load m may be raised above p_1 . And since a single effort, equal to f , will rupture the piece, it is evident that as m approaches f the limits between which we can continue to work our specimen indefinitely will become narrower by the approach of n towards m .

Similarly, as the lower limit passes below the zero point and is therefore changed into a stress of the opposite sign, the mean value of the stress diminishes, and hence the distance through which the piece can

be worked increases, this maximum range being $2 p_2$ when $n = p_2$ and $m = p_2$.

These "new formulæ" for dimensioning are therefore seen to be very simple in form and rational in conception.

Now, how can a single test to rupture on a testing machine give us valuable information in regard to the ability of the material to with-



stand the fatiguing action resulting from repetitions or reversals of stress? We have seen that the fatigue results from too many foot-pounds of work being demanded of the material at one time. Does the ordinary test tell us anything about the amount of work a given material is capable of repeating indefinitely? Not exactly; but it does tell us now many foot pounds of work is required to rupture the specimen at one effort, and it would be reasonable to suppose that a material capable

of doing a greater amount of work at a single effort could also indefinitely repeat a greater amount of work. There is abundant evidence that this is true,* but what the exact relation is between the maximum work at a single effort and the maximum work that can be indefinitely repeated has not been determined. It is the writer's opinion that there is such a relation, and that therefore a single test to rupture will yet tell us the approximate values of p_1 and p_2 , the repetition and reversal limits for that material.

The number of inch-pounds required to rupture one cubic inch of the tested material is given directly by a strain diagram, such as shown on the plate. The vertical co-ordinates represent stress per square inch, and the horizontal co-ordinates represent per cent. of elongation in inches, of a specimen one inch long. The area of the curve will thus represent the number of inch-pounds of energy absorbed by one cubic inch of the specimen before rupture occurred. These areas are given on the plate for cast iron, wrought iron, mild, medium, and hard steel. From any single specimen test of a given material such a diagram may be obtained, the area of which represents the numbers of inch-pounds required to rupture a cubic inch of the material at a single test. This is the Modulus of Ultimate Resilience. The Modulus of Elastic Resilience is the area of the curve within the elastic limit.

It is very evident that we cannot in practice subject our specimens to repeated stresses for the purpose of determining for each specimen the values of p_1 and p_2 . But if a general relation is found to hold between the area or form of the stress diagram, including the elastic limit possibly and the ultimate and the elastic resilience, then from a single test to rupture we can determine these, and from these determine the values of the repetition and the reversal limits. The time seems to be ripe for entering upon such a line of investigation.

The Effect of a Single or of a Few Loadings Beyond the Elastic Limit.

The opinion is currently held, even among engineers, that if a member of a structure, or a piece of metal, has been strained, or distorted beyond its elastic limit, that it has been permanently injured. There is no truth, whatever, in this belief, further than that the permanent distortion may unfit the member for the purpose for which it was originally intended. The metal itself has not only not been injured, but for many purposes it has been improved. It is not generally known that *any metal is (almost) perfectly elastic up to the limit of its greatest previous loading.*

The word almost is put in parenthesis to indicate that it is so nearly perfectly elastic that for one or two or three repetitions no appreciable lengthening would be observable from repeating the maximum load, whereas if many thousands of repetitions should be made the member would be found to gradually lengthen slightly. Thus if a piece of wrought-iron, whose elastic limit is found at 30,000 pounds to the square inch, be loaded to 40,000 pounds to the square inch, the elastic limit has now become 40,000, or if loaded to 45,000, it is found to be (nearly) per-

* see especially a paper by Benj. Baker before Am. Soc. Mech. Engrs., entitled, *Some Notes on the Working Stress of Iron and Steel*, Vol. VIII. (1887), p. 157.

fectly elastic up to 45,000 pounds. Thus if it is desired to use a given iron rod in a machine or structure, for a very limited number of repetitions, say less than 10,000, up to a unit stress of say 40,000 pounds to the square inch, without its becoming distorted in its use, it would only be necessary to load it, in a testing machine, or otherwise, to say 45,000 pounds to the square inch, when it would be found as elastic as steel up to the working limit of 40,000 pounds. This operation might be called *taking the stretch* out of the metal, just as we speak of taking the stretch out of a rope. If this metal were now to be subjected to repeated stress of, say, 30,000 pounds to the square inch, it would not carry this stress as many times as if it had not been already loaded so high. That is to say, there is less capacity for work left in the piece than if the stretch had been left in it. It is only in machines that many hundreds of thousands of repetitions of maximum stresses occur, and hence it is here that the fatigue of metals is of most importance. In a roof truss, for example, where the maximum loads are never repeated perhaps as many times as the structure will see years of service, it would be a matter of no consequence if the iron members had at one time been loaded far beyond their elastic limits. The same would hold for highway bridges, and perhaps for railway bridges, since the *maximum* loads seldom come on such structures.

Another effect of loading a member beyond its elastic limit is that it greatly increases its ultimate strength, and diminishes its total elongation.

That is to say, if 50,000-pound iron be stretched to 40,000 or to 45,000 pounds and there left for several days or weeks, and again tested, it will show a strength of perhaps 60,000 pounds,* but the total elongation will be perhaps only 15 or 18 per cent., instead of 25 per cent., its normal elongation on a single test.

This property of iron is generally utilized in the manufacture of chains, especially such as are intended to have a given pitch, for working sprocket wheels and the like. They are made too short, and then stretched to the required pitch, the stress then being greater than will ever come on the chain in actual use. The result is the chain may con-

* Since the reading of this paper, the writer has made the following tests on $1\frac{1}{4}$ inch square bar iron. The bars were put in the machine without preparation and broken. After periods of 1, 7, and 22 days, ends of the broken specimens, which had been strained up to the breaking limits on the first tests, were again put in and broken, with the following results:

EFFECT OF STRAINING IRON BEYOND ITS ELASTIC LIMIT.

No. of Spec.	Date of first test.	Date of second test.	Unit strength, first test.	Unit strength, second test.	Period of rest.	Increase of strength.	Percentage of increase of strength.
VI...	Jan. 26.	Jan. 27.	51,040	58,300	1 day.	7,260	16.9
IX...	"	"	49,150	58,800	"	8,540	
X...	"	"	50,400	58,940	"	9,650	
I....	"	Feb. 2.	49,940	61,750	7 days.	11,810	22.6
XV...	"	"	50,550	61,450	"	10,900	
XVII	"	Feb. 17.	49,150	62,060	22 days.	12,910	26.8
XXII.	"	"	48,270	61,500	"	13,230	

The total reduction of area was considerably less on the second break than it was on the first. The average elongation on the first tests was 22 per cent. in eight diameters, and the average reduction of area was 35 per cent. The average elastic limit was 28,000 pounds per square inch.

tinue to be used up to this limit without further stretch, and its ultimate strength is also greatly increased.

Similarly if some of the eye-bars of a bridge were by accident made too short, I see no good reason why they should not be stretched to the proper length and then used. I believe it has not been shown that the modulus of elasticity is changed by stretching beyond the elastic limit, and if not, then no harm would be done by slightly stretching them.

All these changes are fully illustrated in the cold drawing of iron or soft steel wires. After being drawn through two or three sets of dies, the wire becomes hard and brittle, but very strong and of a high elastic limit. Before they can be further reduced they have to be annealed, when they are again reduced to the original condition of the material. This would also hold true for large bridge members, for example, if annealed after being loaded beyond their elastic limit.

SHAPES OF TEST SPECIMENS.

1. *Form of Shoulder.* All modern testing machines hold the specimen by friction clutches. If the specimen be of a uniform cross-section it will always break in the grips. It must be reduced in section, therefore, between the gripped ends. This reduction should be by very gentle slopes, so as to give a gradual reduction of area. If the area be suddenly reduced, as by a square and shoulder, all stresses carried by the outer fibres in the ends are suddenly concentrated into the exterior fibres on the reduced section, and if the material has little ductility, rupture begins by tearing apart of these fibres before the interior fibres are brought to their full stress. In cast iron and hard steel specimens, therefore, great care must be taken to reduce as gradually as possible.

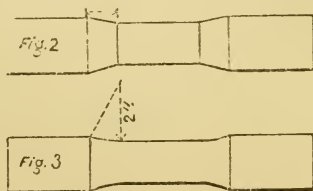
The amount of the reduction should also be only enough to insure rupture in the body of the bar instead of in the grips. Ten per cent. is usually sufficient for this. Figures 2 and 3 illustrate these points.

2. *Length of Reduced Section.*

It has become common to specify that the ductility shall be obtained from a test on a specimen eight inches in length. The ductility is inferred from both the percentages of ultimate elongation and of reduction of area. It is well known that different lengths give different percentages of elongation, on account of the greater or less relative influence of the reduced portion.

Any ductile material draws down at the ruptured section some fifty per cent., and this enormous reduction of cross section is limited to a length of section equal to about one and a half or two diameters. If two specimens be taken, therefore, both eight inches long, one one-half inch in diameter, and the other one inch in diameter, the necked down portion of the one will be, say $\frac{3}{4}$ inch long, and the other $1\frac{1}{2}$ inch long.

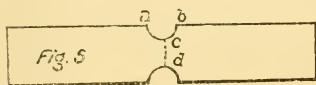
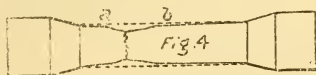
But this excessive elongation is credited in the one case to a length of sixteen diameters, while in the other to only eight diameters. The



same material will give, therefore, a much greater percentage of elongation for the inch bar than for the half inch. The remedy is evident. The elongation should always be taken from specimens the same number of *diameters* in length, *eight diameters* being a very convenient length. This action of the specimen is shown in Fig. 4. Although the entire reduced section is somewhat reduced in area, and has been correspondingly elongated, a large part of the total elongation has occurred in the portion *a b*, in the vicinity of the point of rupture.

THE GOVERNMENT SPECIFICATIONS FOR BOILER PLATES.

In the government specifications for marine boilers, the form of the test piece is shown in Fig. 5. The ductility is judged only from the reduction of area. The reduced section is here so short that the reduction shown is less than it would be on a longer section. But the elongation is a much better test of ductility than the reduction of area, and that cannot be determined from such a specimen. It evidently would not do to measure from the points *a* and *b* before and after the test, for the elongation, whatever it might be, should certainly not



be charged to the entire distance *a b*, since most of it evidently occurred on the smaller portion of this reduced section. The bar should be cut down to the form of Fig. 2 or Fig. 3, the reduced section being some six or eight inches in length.

BRICK AND STONE IN COMPRESSION.

In all substances of a homogeneous or a granular texture, as stone, brick, or cast iron, subject to direct crushing, failure occurs by shearing on surfaces making approximately 45 degree angles with the direction of the thrust. In order to give these shearing stresses a fine opportunity to act, the dimension of the specimen in the direction of the thrust should be not less than one and a half times its greatest lateral dimension. Most tests on substances have been in cubes, but such results are uniformly too great. In the case of a brick, a crushing test made flatwise, on one brick, is very misleading. From three series of tests on standard St. Louis brick, from as many manufacturers, fifty brick being tested for each firm, I have concluded that a brick, crushed endwise, will always carry considerably more than the same brick will stand in a wall. I took 24 brick graded from medium red to paving, and tested them endwise, and then 24 brick similarly graded cut into halves, and four half bricks piled into a column with thin joints of neat Portland cement and left to harden for three weeks. The average strength of the endwise test was 3,532 pounds to the square inch, and of the flatwise column test was 2,625 pounds to the square inch, showing that the endwise test gave a strength about one-third more than the flatwise test, piled four high. All these brick were dry pressed, one lot hydraulic pressed, one mechanically pressed, and one made with a hammer blow. Those made by the mechanical pressure were considerable stronger than the average, and those by the hammer blow the weakest.

Stone and brick lose a large part of their strength when thoroughly

wet. If their strength is required in foundations, or where they receive their full load when water-soaked, then they should be tested wet. If they are to withstand the action of frost, then the amount of absorption is important, anything over twelve per cent. being objectionable, and liable to disintegrate from freezing.

RESILIENCE.

The strain diagrams shown on the plate are useful in showing the value of the material in the absorption of energy, or in resisting shocks. The areas of these curves, given in inch-pounds, represent the number of inch-pounds of energy, or work, which the corresponding material will absorb, or resist, per cubic inch of metal where the stress is direct tension, and is called the modulus of ultimate resilience for that material. Thus one pound, falling 66 inches, would rupture a piece of cast iron one inch square and one inch long. If it were 12 inches long and $\frac{3}{4}$ inch in diameter it would also just be sufficient to absorb the energy of the blow, if causing simple tension in the member.

On the other hand, one cubic inch of wrought iron, of the quality shown by the strain diagram, would withstand, in direct tension, the shock of one pound falling 13,380 inches, or of 100 pounds falling 134 inches. This cubic inch of metal might be of any length, or cross section, and still just be strained to rupture by the blow.

TESTS AT HIGH TEMPERATURES.

Obviously all materials should be tested under conditions as nearly as possible identical with those to be encountered by the structures made from these materials. Thus boiler plates should be tested at temperatures as high as they will ever attain in practice. The greatest pressures come at the highest temperatures, and if these are from 300 to 500 degrees Fahrenheit then the specimen tests should evidently be at these temperatures. I am now preparing to make such tests at the University Testing Laboratory. It is stated that steel boiler plates lose a large part of their ductility at these high temperatures; in other words, that they are "red-short." It is of the greatest importance to determine this fact and to accurately evaluate the effects of such temperatures.

ECONOMICAL HEIGHT OF BRIDGE TRUSSES FOR A GIVEN PANEL WIDTH.

BY JOHN LUNDIE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read October 4, 1887.]

The following interesting result regarding the economical height of a bridge truss with a given panel width, will probably be of interest to the Society. The writer's attention was called to the same by Mr. Hopper, Engineer to the Pacific Bridge Company, while engaged, in conjunction with him, on bridge work on the Pacific Slope.

The greatest economy in a bridge truss with a given panel width is obtained when the cost of the chords equals the cost of the vertical members

plus the cost of the diagonals multiplied by the cosine of twice the angle of their inclination.

Appended is mathematical demonstration of same :

Let C_1 = weight of material in upper chord,
price = p_1 .

C_2 = weight of material in lower chord,
price = p_2 .

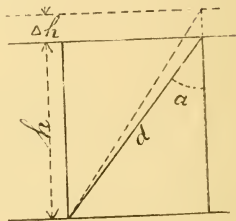
V = weight of material in vertical members,
price = p_3 .

D = weight of material in diagonal members,
price = p_4 .

h = height of truss.

d = length of diagonal member.

a = angle of inclination of diagonal.



$$d = \frac{h}{\cos a} \quad \Delta d = \Delta h \cos a$$

$$D \propto \frac{d}{h} \times d \propto \frac{d}{h}$$

Then when the height of the truss is increased by the increment Δh the following differences in price of members will result :

$$\begin{aligned} \text{Chords} \quad & (C_1 p_1 + C_2 p_2) \left(1 - \frac{h}{h + \Delta h} \right) \\ & = (C_1 p_1 + C_2 p_2) \left(\frac{\Delta h}{h + \Delta h} \right) \end{aligned}$$

$$\begin{aligned} \text{Vertical members} \quad & V p_3 \left(1 - \frac{h + \Delta h}{h} \right) \\ & = - V p_3 \frac{\Delta h}{h} \end{aligned}$$

$$\begin{aligned} \text{Diagonal members} \quad & D p_4 \left(1 - \frac{(d + \Delta d)^2}{h + \Delta h} \times \frac{h}{d^2} \right) \\ & = D p_4 \frac{\Delta h}{h + \Delta h} \cos 2a \end{aligned}$$

When the price is a minimum the sum of these differences will equal zero:

$$\begin{aligned} (C_1 p_1 + C_2 p_2) \frac{\Delta h}{h + \Delta h} - V p_3 \frac{\Delta h}{h} - D p_4 \frac{\Delta h}{h + \Delta h} \cos 2a &= 0 \\ C_1 p_1 + C_2 p_2 &= V p_3 + D p_4 \cos 2a. \end{aligned}$$

DISCUSSION.

Mr. SCHERZER : I have examined Mr. Lundie's paper with a view to ascertaining whether the results obtained by him could be applied practically. The title does not specify any particular type of truss, and it would appear from this that the investigation is general and includes all types; this, however, is not the case, as the mathematical demonstration appended takes into consideration a single panel of a Pratt truss only, and proves that the cost of the two parallel chord members is equal to the

cost of the vertical member plus the cost of the diagonal member multiplied by the cosine of twice its angle of inclination. In order to arrive at this conclusion certain assumptions are made which the author does not clearly state in the premises, but which can easily be obtained from the mathematical investigation; they are substantially as follows:

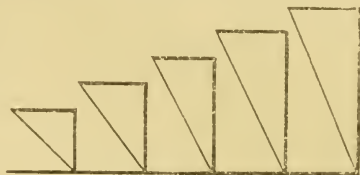
- 1st. The cost of each member varies directly as its weight.
- 2d. The weight of chords varies inversely as the depth of truss.
- 3d. The weight of vertical members varies directly as the depth of truss.

4th. The weight of diagonal member varies directly as $\frac{\text{Depth of truss}}{\cos^2 a}$

in which a represents its angle of inclination.

These assumptions do not take into consideration any strut formula for compression members, nor pin-plates, lattice-bars and tie-plates, all of which affect the weight of a truss materially. Even granting the above assumptions to be correct, I fail to see how the economical depth established for a single panel can be applied to a whole truss, since it is evident that the depth must vary for each panel up to the centre of truss, for the reason that the chords increase and the web members decrease in weight from the ends to the centre of truss.

If the economical depth for each panel be determined by the author's formula, and the panels placed side by side, they will form a figure, disconnected as indicated by sketch.



But this figure does not represent a bridge truss, at any rate not a Pratt truss.

Mr. LUNDIE: One little step further, Mr. Scherzer, and you will develop a bowstring truss.

RAPID RAILWAY EMBANKMENT CONSTRUCTION.

BY ISAAC A. SMITH, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read December 21, 1887.]

The object of this paper is not to give you information upon new engineering topics, but to describe the methods adopted in performing a certain given amount of work in a brief period of time. The difficulties that have been overcome in the work about to be described were more from a shortness of time than from any other cause. The work is located in the city of St. Louis, namely, on Hall street, between North Market and Bremen avenue. A franchise was granted to a certain railway corporation in this city to build its railway tracks over and upon certain portions of various streets and wharves in the city of St. Louis, which, among other things, required that the railroad company should "fill Hall street forty feet wide to the established grade within one year" from the date of the approval of the ordinance granting the franchise. Certain difficulties were in the way, and were not removed until

all the time mentioned in the ordinance had expired excepting twenty days. The amount of work required to be done to comply with the terms of the ordinance and save its being forfeited, namely, that of filling Hall street forty feet wide to the established grade from North Market street to Bremen avenue, involved the building of an embankment about a mile and a quarter in length, requiring about 97,500 cubic yards of material. All of this material had to be obtained from points outside of the limits of the streets, it being an embankment the whole distance. Two borrowing pits were secured near the centre of the the work, with an average haul from the borrowing pits to the place of deposit in the road of about 1,300 feet. These borrowing pits were composed wholly of silt, and situated upon the west bank of the Mississippi River. The first work performed was that of building a road from the borrowing pits to the embankment. This was done by cutting down the willows which grew over the borrowing pit, and between it and the street upon which the embankment was to be constructed, and laying them crosswise of the road and putting dirt upon them to hold them down, the road of course being simply a temporary one for use during the time of construction. After clearing all of the logs, stumps and other débris from the surface of the pits, which required two days, on the morning of the third day the work of constructing the embankment began. Sixty two-horse wagons were placed in service for each pit, making one hundred and twenty in all. A space was opened in each pit of sufficient width to load twenty wagons at one time, and seven men were detailed for each wagon, making one hundred and forty men, exclusive of a foreman in each pit. After the wagons were loaded they were driven straight forward, without turning, to another road already constructed, and following this road conveyed their load to the place of deposit. When the wagon reached the place of deposit, or dump, as we call it, it was driven on to the dump to a place designated by the dumpman. If by any accident or fault of the driver or horses the load was stopped short of the point designated it was at once unloaded, for the orders were strict against permitting teams to pull a second time on a load after it was stopped on the soft dump. The wagon, after being unloaded, proceeded over the forward end of the dump to the road in the pit. A ticket boy, provided with a sufficient number of tickets, all alike, handed one to the driver of the wagon as he passed going to the pit. Drivers were required to exhibit forty of those tickets for a day's work. The tickets were returned to the time-keeper every evening. Each wagon was numbered, and each shoveler and dumper was numbered. Men and teams were known only by their numbers. Their numbers appeared upon the time-book instead of their names. The object in doing this was to prevent a multiplication of similar names, which is often a source of serious error in keeping time on large works. There was one walking foreman in each pit, whose business it was to preserve order among the men and direct where the wagons were to be loaded. The men were not allowed to speak to each other, neither were they allowed to smoke or drink. Teamsters were not allowed to leave their seat upon the wagon. Men were employed, who carried water and watered the horses when

they needed it. Ice water was carried to the men when it was needed. If a man was derelict in his duties, or was falling behind in the performance of what was expected of him, the foreman would warn him first that he must do better. If a second warning was necessary it came in the shape of a discharge, the foreman being provided with a pad of blank discharges requiring a very small amount of writing, one of which he made out and handed to the discharged employé, who conveyed it to the time-keeper, and from the time-keeper he received a check on the treasurer for his money, his number being preserved after he was discharged, and a remark made opposite the number in the time-keeper's book stating the cause of his discharge. If the cause was not through any fault of his own, if it was from sickness of himself or family, or from any cause that he could not control, there was no objection to his being re-employed ; but if his discharge was occasioned by laziness, desire to drink, or any fault of his own, he was not re-employed. Each pit foreman was provided with a staff eight feet long. Three feet and three inches from the end of this staff was a notch cut in it. There was also a notch cut twenty inches from the end. The length of the staff indicated the required length of the wagons. The first notch mentioned, namely, the one three feet and three inches from the end, was the required width of the wagons, and the twenty-inch notch was the required depth, and no wagons were permitted to enter the pits that did not comply exactly with these dimensions. The wages paid to teamsters was \$4 per day ; to walking foremen, \$2.50 per day ; time-keeper, \$2.50 per day : dumpmen and shovelers, \$1.50 per day ; ticket boys, \$1 per day.

The second pit was operated precisely as has been described for the first one. The embankment had been properly staked out by the engineers, slope stakes with the fills marked upon them at frequent intervals, and skilled dumpmen were secured where it was possible to do so. The work from these two pits proceeded in this manner until the 97,500 cubic yards of material had been deposited in the embankment. However, all of the material required for the embankment did not come from these pits. There were some cellars being dug in the vicinity and some street reconstruction ; from both of these sources some material were obtained, it being hauled to the dump by the contractors for these respective works. A separate system was observed for this character of work. The teamsters were each given a ticket for a load. The tickets were printed and were numbered serially, and each of them contained the autograph signature of the chief engineer. This was done to prevent counterfeiting. These tickets were redeemed at the office of the company in quantities exceeding ten, and ten cents apiece was paid for them generally. The wagons which conveyed this outside material to dump were of different sizes. Some of them would contain more than a yard and some less. In sixteen days from the time the work began it was finished forty feet wide to the established grade ; that is to say, within a period of sixteen days 97,500 cubic yards of material was deposited in Hall street between North Market and Bremen avenue. The embankment was about ten feet high and forty feet wide on top. It is usually the case that where work of this character

has to be *rushed*, or done within a given period of time, that little or no attention is given to the cost of the work, but in this instance the cost was a very important matter, and every point was closely watched so as to secure a minimum price per cubic yard for this embankment. Before the company concluded to do the work itself a number of prominent contractors were requested, after visiting the premises, to make bids for doing the work, accompanied, of course, by a guarantee that it would be done within the time required, namely, twenty days. No contractor would give that kind of guarantee, and the lowest price to be obtained from any of the contractors for this work without a guarantee was 35 cents per cubic yard. The actual cost of doing the work in the manner described was eighteen and fifty-eight hundredths cents per cubic yard, which was but little more than one-half of what it would have cost had it been let to the lowest bidder for the work. The weather, during the time the work continued, was very mild and pleasant, conducive to the largest results in a given period. The character of the material conveyed from the borrowing pits to the embankment was such that it required no picking or ploughing, but could be readily shoveled, being silt deposit from the river. Care was taken in the pits to see that the surface of the ground was taken off evenly, consequently loaded wagons very rarely "stalled" in the pit, or got in each other's way. However, an extra team was kept in each pit to help loaded wagons if there was any tendency to stall on the part of the horses attached to the loaded wagon. Not more than one pair of horses was required, however, to over twenty teams. The utmost harmony prevailed among the men; no talking was permitted, as I have before remarked, and at noon hour the men were required to take their lunch as near as possible to the scene of their operation. Work began at half past six in the morning, ended at half past five in the evening, and one hour for feeding at noon, which left ten working hours.

Several eminent local engineers, knowing the extent of the work, gave it as their opinion that it could not be done in the limited time, and the writer confesses that he was of the same mind; but there was no alternative but to try; and favored with fine weather, excellent materials and thorough organization, the task was accomplished within the allotted time.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

FEBRUARY 15, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 7:40 P. M., President Rice in the chair. thirty-eight Members and seven visitors present.

The record of the last meeting was read and approved.

Messrs. Joseph Coulson, Jr., C. Atherton Hicks and John H. Webster were elected Members of the Society.

The following were proposed for membership: Charles A. Allen, of Worcester, recommended by F. P. Stearns and Dexter Brackett; Frederic W. Bateman, of Fitchburg, recommended by E. K. Turner and John Worcester; Charles W. Drake, of Boston, recommended by F. M. Miner and H. C. Keith; X. H. Good-nough, of Brookline, recommended by F. P. Stearns and G. W. Hamilton; Charles W. Mason, of Boston, recommended by M. T. Cook and Sophus Haagensen; William Parker, of Allston, recommended by Walter Shepard and H. C. Keith; and Arthur L. Plimpton, of Roxbury, recommended by F. P. Spalding and H. H. Carter.

The Secretary announced the resignation of Mr. Fred. B. Sherburne, of Denver, Colorado.

The Secretary read a communication from Mr. E. L. Corthell, of Chicago, Member of the Society, in relation to the work of the Council of Engineering Societies on National Public Works. The communication was referred to the Committee on National Public Works.

An invitation to the Members to attend the sessions of the Institute of Mining Engineers at its coming convention in this city was received from the local committee of arrangements.

On motion of Mr. Stearns it was voted that Mr. Henry Manley be appointed a committee to arrange for the annual dinner, and that the sum of fifty dollars be appropriated for the general expenses of the dinner, and placed the disposal of the Committee.

On motion it was voted that a committee of three be chosen by nomination at large, to present in print at the next meeting a list of candidates for officers of the Society for the ensuing year, three names to be presented for each office. The committee chosen were Messrs. F. P. Stearns, F. L. Fuller and Fred. Brooks.

Mr. Frederick Brooks read a paper entitled "Sewage Disposal at Medfield, Mass.," which was discussed by Messrs. Billings, Fuller, Heald, Kimball and Stearns.

Mr. Wilbur F. Learned gave some facts relating to the chemical treatment of

Mystic sewage, and Mr. Chas. H. Swan gave some statistics in relation to the treatment of sewage abroad.

[Adjourned.]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

FEBRUARY 1, 1888 :—286th Meeting—The Club met at 8:15 P. M., at Washington University, President Holman in the chair, thirty-five Members and two visitors present. The Secretary being absent, J. B. Johnson was asked to act in that capacity. The following names were proposed for membership : E. H. Connor, indorsed by J. B. Johnson and C. M. Woodward ; John B. Quigley, by Geo. W. Dudley and Frank H. Pond ; E. C. Parker, by W. T. Angell and W. H. Bryan.

The Committee appointed at last meeting to report to the Club suitable action on Mr. Waddell's efforts to reform the present practice in the building of highway bridges reported as follows :

St. Louis, Feb. 1, 1888.

TO THE ENGINEERS' CLUB OF ST. LOUIS :

Your Committee appointed to consider what action should be taken on Mr. Waddell's invitation to indorse him in his efforts to raise the standard of the highway bridge practice in this country beg leave to report as follows :

Resolved, That this Club express their approval of the pamphlet entitled "General Specifications for Highway Bridges of Iron and Steel," by J. A. L. Waddell, and deem it a well-considered effort to bring about a much-needed reform.

That we recommend these specifications to the consideration of county and town boards as calculated to give structures both safe and economical when faithfully carried out, but that to insure these results competent engineering supervision is absolutely necessary.

That in the letting of highway bridge contracts and in the acceptance of the finished structures such boards should, in all cases, call to their aid a competent civil engineer, and thus insure at once the public safety and the wise expenditure of the public funds.

Committee } J. B. JOHNSON,
 } ROBT. MOORE,
 } N. W. EATERS.

The report was accepted and the Committee discharged. After a discussion by Messrs. Seddon, Johnson, Mersereau, McMath, and Col. H. C. and Robt. Moore, the report was laid on the table with notice that it would be called up in two weeks.

The following resolution was moved by R. E. McMath:

Whereas, The United States Signal Service, without increase in force or expense, if equipped with suitable instruments, can make observations of the rate and duration of rainfall, and thereby furnish information of great scientific value, and of the utmost practical importance in the solution of questions of water supply and drainage of cities ; therefore,

Resolved, That the Engineers' Club of St. Louis fully indorse the suggestion recently made by the Chief of the Signal Service that self-registering rain gauges be provided at all observation stations ; also,

Resolved, That we request the committees of the two Houses of Congress to insert in the next appropriation bill an item to cover the cost of such instruments.

This resolution was unanimously adopted. Mr. Carl Gayler then read a paper on "Highway Bridge Floors," giving several standard designs, with their weights and cost. The paper was discussed by Col. and Robert Moore.

Mr. B. F. Crow read a paper on "Constructive Accounts," showing how the cost of the material and labor required to produce each integral part of a street car is found, by means of labor and material accounts with all the orders. One man does all the work due to this system of accounts for 150 workmen. Blank forms were shown and the method described in detail.

After a general discussion of this paper, Club adjourned.

J. B. JOHNSON, Secretary pro tem.

FEBRUARY 15, 1888 :—287th meeting.—The Club met at 8:10 P. M., at Washington University, President Holman in the chair; thirty Members and four visi-

tors present. The minutes of the 286th meeting were read and approved. The Executive Committee reported its meeting of February 11th, recommending Edward H. Connor, E. C. Parker and Bathurst Smith for election to membership. They were balloted for and elected.

On motion, the report of the special committee on the "Waddell Pamphlet on Highway Bridges" was taken from the table. After a very general discussion and the proposal of a number of substitutes, none of which met with the Club's approval, the matter was made the special order of the day for the next meeting.

The Secretary reported having sent copies of the resolutions adopted at the last meeting on the subject of self-registering rain gauges, to members of Congress interested. He also announced that he had received, for the Club, a copy of the 1883-87 report of the aqueduct commissioners of New York on the new Croton aqueduct.

Mr. O. L. Petitdidier offered an apology for his late appearance, having reached the city after 8 o'clock and having come direct to the Club. He then presented a paper on "Practical Notes on Masonry and Stone Laying." He called attention to the great antiquity of the subject and its interest to engineers. He mentioned many points of value in such construction, and necessary precautions to be taken. The quality of the stone was of prime importance, and he read the government specifications on the subject. Among other points touched upon were mortar, cements, sand, pointing, expansion, laying masonry, transportation and plant. Messrs. Holman, Seddon and Johnson took part in the discussion. Papers by Prof. H. B. Gale and S. F. Burnet were announced for the next meeting.

[*Adjourned.*]

W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 7, 1888 :—The 244th regular meeting of the Western Society was held at 8 P. M., at the hall of Society. In the absence of the president, Mr. Artingstall was made chairman *pro tem*.

The minutes of the annual meeting were read and approved.

The following were proposed for membership :

Charles B. Parsons, assistant engineer, Town of Lake, Ill.; S. Lee Heidenreich, draughtsman, formerly assistant engineer at Pullman, and on railway construction, Chicago, Ill.; Robert A. Shailer, engineer bridges and buildings, C., M. & St. P. Ry., Chicago, Ill.

The following were elected Members of the Society : E. L. Corthell, 205 La Salle street, Chicago, Ill.; William T. Casgrain, Milwaukee, Wis.; Charles Poore, 171 La Salle street, Chicago, Ill.

Mr. Cooley, for the Committee on National Public Works, reported progress, and intimated that the Committee would report for instructions at the next meeting of the Society.

The amendments to the By-laws, submitted at last meeting, and proposing an increase in the annual dues, were ordered submitted to letter ballot.

A communication from the Board of Managers for the Association of Engineering Societies submitted bills for January assessment of \$190, and for Board expenses of \$29.10. These were ordered paid.

A communication from a committee of the American Society of Civil Engineers, requesting the Western Society to join in a petition to Congress for special provision in regard to rainfall observations by the Signal Service Bureau, was referred to a special committee to be hereafter appointed.

There being no topic or paper for discussion, Mr. Cooley gave a résumé of a

brief upon the "Lakes and Gulf Waterway." It was suggested that copies be sent to Members of the Society, and that it be made a topic of discussion.

[Adjourned.]

The President announces the following committees:

STANDING COMMITTEES.

Board of Managers for Association.—B. Williams, L. P. Morehouse.
 Finance.—Chas. Fitz Simons, D. C. Cregier, O. B. Green.
 Library.—C. L. Strobel, S. S. Greely, G. A. M. Liljencrantz.
 National Public Works.—L. E. Cooley, H. B. Herr, Chas. Fitz Simons.
 Harbors and Waterways.—E. H. Corthell, O. M. Poe, S. G. Artingstall, T. T. Johnston.

SPECIAL COMMITTEES.

Specifications for Highway Bridges.—C. L. Strobel, E. C. Carter, A. Gottlieb.
 Better Provision for Rainfall Observations by the Signal Service.—B. Williams,
 Chas. MacRitchie, L. E. Cooley. L. E. Cooley, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

OCTOBER, 11, 1887:—Regular meeting held, President Whitelaw in the chair. Minutes of the last meeting were read and approved.

Mr. Latimer, Chairman of the Committee on resolutions of respect to Mr. Holloway, requested further time, as he had been out of the city.

Mr. Wood, Chairman of the Committee on Scientific Pursuits, stated that a paper had been expected from Prof. Morley for the evening, but as the notices of the meeting did not announce such paper it was supposed that other arrangements had been made. No paper was read.

Mr. Rawson stated the action taken by the Board of Managers of the Association in regard to calling a convention to promote a closer union among the various engineering societies of the country, and offered the following resolution which, after some discussion and amendment was adopted. *Resolved*, That the Civil Engineers' Club of Cleveland favors calling a convention of the several societies forming the Association of Engineering Societies and such other similar societies as may wish to co-operate for the purpose of considering the project of a closer union of all such organizations, as suggested in the address of the Board of Managers of the Association at its meeting of April 15, 1887, in Chicago. This Club hereby authorizes and requests the Board of Managers to call a convention of delegates from the various societies, to be held at such time and place as said Board may select.

Mr. Latimer stated that the Roadmasters' Convention was in session, and that on the following day its members would visit points of interest about the city, and suggested that the Club appoint delegates to accompany them. On motion, the following gentlemen were appointed as such delegates: Messrs. Latimer, Searles, Reid and Rawson.

[Adjourned.]

JAMES RITCHIE, Secretary pro. tem.

NOVEMBER 8, 1887:—Regular meeting held, President Whitelaw in the chair; 25 Members present.

The application of John P. Cowing for Active Membership was read, and as the Committee on Membership made two reports, the majority recommending him for Associate Membership, the matter was postponed until the next regular meeting.

The President read a communication from Mr. C. M. Barber, tendering his resignation as Secretary of the Club, on account of removal from the city. On motion of Mr. Rawson the resignation was accepted.

Professor H. A. Wood, of the Case School of Applied Science, read a paper entitled "Curiosities of Mathematics," which was followed by problems and discussions. On motion of Mr. Walker a vote of thanks was tendered to Prof. Wood for his interesting and instructive lecture.

[*Adjourned.*]

JAMES RITCHIE, Secretary pro. tem.

NOVEMBER 22, 1887:—Semi-monthly meeting held, with President Whitelaw in the chair. Minutes of the last meeting were read and approved.

Mr. Walter Miller read a paper on "Triple Expansion Engines," illustrated by black-board diagrams.

Mr. M. L. Deering read a paper on "Vulcanizing Wood Pulp," illustrated by showing samples of the articles he produces.

Both papers were very generally discussed.

The following resolution by Mr. Rawson was adopted:

Resolved, That the thanks of the Club are due, and are hereby tendered to our late Recording Secretary, Mr. Clarence M. Barber, whose resignation was accepted at our last meeting, and who for the past two years has served the Club so faithfully as its Secretary; and that our best wishes attend him in his new location at Idaho Springs, Colorado.

[*Adjourned.*]

JAMES RITCHIE, Secretary pro tem.

DECEMBER 13, 1887:—Regular meeting held, President Whitelaw in the chair. In the absence of the Secretary the business of the meeting was dispensed with.

Mr. C. O. Arey read a paper entitled "A Foundry Roof, Supporting Cranes." A discussion followed, during which Mr. C. G. Force explained the construction of a roof designed by him for the Cleveland Rolling Mill Co.

President Whitelaw stated that he had received a letter from the American Water-Works Association, informing him that the next annual convention of the association would be held in Cleveland. He thought it would be proper for the Club to take some steps toward entertaining the members of the association.

Mr. Latimer requested further time in which to prepare resolutions of respect to Mr. Halloway, as both Mr. Jones and he had been unavoidably absent from the city.

By request, Mr. W. H. Searles, Member of the Committee on National Public Works, made a few remarks outlining the work of the Committee, but desired that his remarks be not recorded, as a full report would soon be made.

[*Adjourned.*]

JAMES RITCHIE, Sec. pro tem.

DECEMBER 27, 1887:—Semi-monthly meeting held, President Whitelaw in the chair.

Mr. Eisenman read a circular sent out by the Executive Board of the Council of Engineering Societies, addressed to the Committee on National Public Works.

Professor E. W. Morley read a paper entitled "A Method of Making the Wave Length of Sodium Light the Actual and Practical Standard of Length." Black-board diagrams illustrated the various experiments made of Professors Morley and Michelson on the above subject.

[*Adjourned.*]

JAMES RITCHIE, Sec. pro. tem.

JANUARY 10, 1888:—Regular meeting held. In the absence of both President and Vice-President Mr. W. H. Searles occupied the chair.

The minutes of the last meeting read and approved. On recommendation of the Committee on Membership the resignation of Mr. J. M. Ackley was accepted.

The resignation of Mr. I. C. Brewer was received and referred to the Committee on Membership.

The Committee of Resolutions of Respect to Mr. Holloway presented the following: "Our former president and valued friend, Mr. J. F. Holloway, having removed to New York, we desire to express to him our profound sense of regret at his departure. Although deprived of his immediate co-operation we have with us the permanent influence of his high professional qualities as a gentleman, citizen and friend, and we now tender him our earnest thanks for his services to this Club both as President and Member. We assure him that his never tiring efforts to promote the aims and prosperity of the Civil Engineers' Club will always be appreciated, and that he takes with him to his new field of labor the best wishes of all its Members for his success and happiness."

(Signed),

CHAS. LATIMER,	} Committee.
E. H. JONES,	
W. H. SEARLES,	
JOHN WALKER,	
H. M. CLAFLEN,	

The Committee recommended the adoption of the report, and that a copy be engrossed, suitably framed and presented to Mr. Holloway, and that it be incorporated in the minutes and printed in the JOURNAL of the Associated Societies. Adopted.

The Committee also recommend that Mr. Holloway be elected an Honorary Member of the Club, which, under the rule, was referred to the Committee on Membership.

The application of Mr. John P. Cowing was recommended for Associate Membership by the Committee.

On motion of Mr. Baker the Committee was instructed to communicate with Mr. Cowing and ascertain his pleasure.

Mr. Charles Latimer read a paper on the "Elevation of the Outer Rail on Railroad Curves."

The reading was followed by a discussion.

The Chairman read a letter from the Corresponding Secretary accompanying a work on the "Theory and Practice of Surveying," presented to the Club by the author, Mr. J. B. Johnson.

On motion, the Corresponding Secretary was instructed to return the thanks of the Club to Professor Johnson for his work.

Works on natural gas were presented by Charles A. Ashburner and Lemuel Bannister.

The Corresponding Secretary was instructed to extend the thanks of the Club for the same, and also to inform Mr. Ashburner where he can obtain the paper of Mr. Christian, of Norwalk, on the "Transmission of Natural Gas Long Distances." [Adjourned.]

JAMES RITCHIE, Rec. Sec. pro tem.

ENGINEERS' CLUB OF KANSAS CITY.

FEBRUARY 6, 1888 :—A regular meeting was held in the Club Room at 7.45 P. M., the following Members being present: J. A. L. Waddell, O. Chanute, C. G. Wade, S. A. Mitchell, E. W. Grant, E. W. Stern, W. Kiersted, C. M. Duncan, W. H. Breithaupt, B. L. Marsteller, T. F. Wynne, Wm. B. Knight, A. E. Swain, K. Allen, and eight visitors.

The minutes of the previous regular meeting and those of the Executive Committee meeting were read and approved.

On motion of O. Chanute it was voted to ballot on an amendment to the Constitution, Art. IV. Sec. 1, to include the Treasurer in the Executive Committee.

By direction of the Executive Committee the Secretary read resolutions approving the Senator Cullom bill now before Congress relative to the conduct of National Public Works, but it was thought best to postpone further action.

The ballots were canvassed by the Executive Committee, resulting in the election of J. A. L. Waddell as Treasurer and H. A. Lasley, A. W. Boeke, and F. L. Miller as Members.

A circular from Mr. J. C. Goodridge, Jr., of New York, regarding derailments was read.

A letter from Mr. Benezette Williams inquiring whether action had been taken with view of the formation of a National Association of Engineering Societies was read, and it was decided to answer that the Club was favorably disposed, and would appoint a delegate or committee when desired.

Mr. B. L. Marsteller read a paper on the "Inspection of Iron Bridges and Viaducts," which was discussed by Messrs. Chanute, Waddell, Breithaupt and Goldmark.

The applications of H. W. Kerr as Member and Geo. P. Sylvester as Associate Member were presented.

The Committee to consider Mr. Waddell's pamphlet on Highway Bridges reported in favor of the stand taken by the author, but thought the indorsement of the Club not in accordance with custom.

On motion by T. F. Wynne, the report was adopted.

It was proposed to invite discussion of the pamphlet by the Club by eminent bridge engineers and bridge builders at the regular meeting of April 2, and it was voted that the Executive Committee take action in accordance with the above.

[Adjourned.]

KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

Address of Retiring President, Engineers' Club of St. Louis. By Wm. B. Potter. Gives brief history of the club and discusses its work and relations with other societies. *Jour. Assoc. Engin. Soc.*, Jan., 1888, pp. 22-28.

Accidents, Train in 1887. Gives a tabular statement showing the number and classification of accidents for 15 years; also shows the casualties to passengers and employés. It shows 1887 to be the worst in our history. *R. R. Gazette*, Jan. 27, 1887.

Arches. An abstract of a paper before the Engineering Section of Bristol Naturalist Society by Mr. C. Richardson, Engineer to Severn Tunnel. *Engineering*, Jan. 13, 1888.

Axle, Standard for 60,000-lb. car. A paper by A. Forsyth, presented to January meeting of Western Railway Club by the committee on axles as their report. It discusses dimensions and loads, factor of safety and friction. *Mast. Mechanic*, Feb. 1888.

— **Standard for 60,000-lb. car.** By H. C. Meade, before January meeting Western Railroad Club. Gives comparison between the Johann and M. C. B. axles. *R. R. Gazette*, Feb. 10, 1888. *Mast. Mechanic*, Feb. 1888.

Boilers. *United States Government Rules for Marine Boiler Pressures.* Pressure allowed for various thicknesses and qualities of plate, flues, etc. *Mechanics*, Jan. 1888.

Brakes, Freight. A paper by H. H. Westinghouse before the New York Railroad Club. Describes the construction, operation and maintenance of brakes. With discussion by the Club. *Mast. Mechanic*, February, 1888; *R. R. Gazette*, Jan. 27, 1888.

Bridge, Harlem River. Gives plan and elevation showing the arrangement of the plant and the condition of the work just before the last segments of span No. 2 were closed. *Eng. and Build. Rec.*, Jan. 21, 1888. False works, skewback segment and hinges are shown in *Eng. News*, Feb. 4, 1888.

—, **Hooghly River, India.** By Sir B. Leslie. A paper before the Institution of Civil Engineers, giving details of the construction of the Jubilee bridge carrying the East Indian Railroad over the Hooghly River at Hooghly. It has a central double cantilever 360 feet long by 52 feet high, and side spans 420 feet long and 47 feet deep. Abstract *Engineering*, Jan. 27, 1888, and *Mech. World*, Feb. 4, 1887.

—, **Kentucky and Indiana.** By Mace Moulton. A paper before the American Society of Civil Engineers, containing a full account of the construction, with extracts from specifications, tables showing tests of materials, etc., of the bridge over the Ohio River, at Louisville. Plates show design, locations, strain sheet and details. *Trans. Am. Soc. C. E.*, Vol. XVII., September, 1887, pp. 111-168; abstract in *Engineering*, Jan. 27, 1887.

—, **North River, Proposed.** By Gustav Lindenthal. Before the American Society of Civil Engineers. Gives very full details of the proposed bridge over Hudson River, at New York. Proposed dimensions are: River span, 2,850 feet; two shore spans, 1,800 feet; width, 68 feet, with six railroad tracks; height above water, 145 feet. Abstracted in *Eng. News*, Jan. 28, et seq, 1888.

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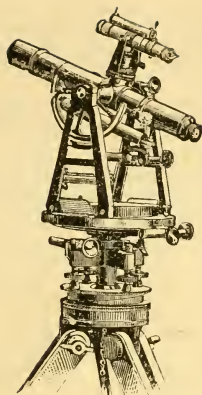
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- Bridge, Willamette River, Oregon.** Gives elevation, cross section and details of a timber Howe truss across the Willamette River, Albany, Oregon. It has two spans 175 feet long, and a draw span 260 feet in length. *Engineering*, Jan. 6, 1888.
- Bridges, Stresses in Lattice, New Method of Obtaining.** By Wm. Robertson. Gives a new graphical method of computing the strains in lattice bridges. *Engineer*, Dec. 30, 1887.
- Canal, Panama in 1887.** By Lieut. C. C. Rogers before the American Society of Civil Engineers. Gives details of the condition of the canal as seen during an inspection trip of nearly three weeks during March and April, 1887. Abstracted *Engin. and Build. Rec.*, Jan. 28, 1888.
- , *Panama.* An abstract of an article in *Le Genie Civil*, giving profile of the proposed canal, with locks, *Engin. News*, Feb. 11, 1883.
- . See Ship Transfer.
- Car Heating, C., M. & St. Paul.** Gives description, with details of couplings, of the system of steam heating now used on the Chicago, Milwaukee & St. Paul Railroad. *Engin. and Build. Rec.*, Jan. 21, 1888; *Railroad Gazette*, Jan. 13.
- Concrete, in Sea Water.** An abstract from the report of P. J. Messent to the Aberdeen Harbor Board. Gives as a cause for the failure of some of the concrete work at the Aberdeen Graving dock, injudicious specification for the cement or improper method of mixing or using it. *Engineering*, Jan. 28, 1888.
- Crane, "Goliath," Twelve Ton steam.** Gives a two page plate showing details of a twelve-ton steam traveling crane. It has a span of 60 feet, and a clear height of 28 feet. *Engineering*, Jan. 13, 1888.
- Dam, Masonry.** By J. W. Hill. A paper before the American Society of Civil Engineers. Gives description of the masonry dam at Eden Reservoir, Cincinnati, and shows the methods of computation used, with discussion and three plates. *Trans. Am. Soc. C. E.*, Vol. XVI., pp. 261-282, June, 1887.
- . *Quaker Bridge. Plan Formation of.* By A. Marichal before the Philadelphia Engineers' Club. Discusses the question whether the dams should be built with a curved or straight line and advocates the former. *Am. Engr.*, Jan. 18, 1888.
- . *Quaker Bridge.* By E. E. R. Tratman. Gives a good review of early history of Quaker Bridge dam and the reasons for its adoption. Illustrated by maps, etc., from the Report of the Aqueduct Commissioner. *Engineer*, Jan. 27, 1888.
- Dams, High Masonry.** A valuable synopsis of research on high masonry dams made by A. Fteley, for the Chief Engineer of the Croton Aqueduct for the purpose of determining the form, dimensions, etc., of the proposed Quaker Bridge dam. Reprinted from the Report to the Aqueduct Commission in *Engin. News*, Feb. 4 and 11, 1888.
- Drilling, Relative Economy of Hand and Machine.** By W. A. Wheeler. Gives a valuable comparison of the cost of hand and machine work from a purely economical standpoint. Shows there is but little difference in the cost. *Jour. Assoc. Engr. Soc.*, February, 1888.
- Earthwork, Filling South Boston Flats.** By F. W. Hodgdon. Gives details of the methods employed by the Commonwealth of Massachusetts to fill 120 acres of South Boston Flats from two feet below to thirteen feet above mean low water. *Jour. Assoc. Eng. Soc.*, January, 1888, pp. 5-9.
- Electric Wave and Phase Indicator,** for alternating and undulatory currents. A diaphragm is made to move a light mirror in harmony with the current vibrations, and the form of the waves is indicated by the movement of a spot of light. In this way photographs of the wave forms may be made. Elihu Thomson in *The Electrical World*, Jan. 28, 1888.
- Electrical Welding.** Abstract of a paper by Professor Rühlmann, giving an account of the process and the description of the advantages which are claimed as resulting from it. Illustrated. *Engineering*, Jan. 27, 1888.
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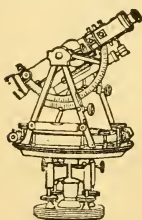
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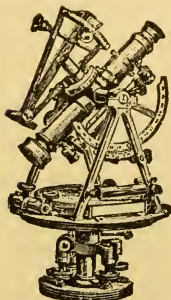
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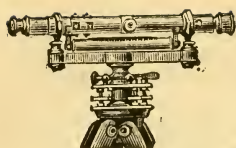
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- , **Davey's Differential Pumping.** Brief description, with two-page plate and other engraving, showing plan, elevation and cross-sections of Davey's differential pumping engine for the Weston Water-Works. *Engineer*, Jan. 13, 1887.
- , **Gas, Atkinson.** Brief description, with indicator diagram, of the Atkinson gas engine, which gave a brake horse-power for 20.5 cubic feet of gas. Illustrated. *Engineer*, Dec. 30, 1887.
- , **Hargreaves Thermo-Motor.** Gives a description, with sectional elevation, of a Hargreaves thermo-motor, which, at 100 revolutions per minute, indicated 40 horse-power. It consumes $20\frac{1}{2}$ lbs. of coal tar per hour. The highest available efficiency is 73 per cent. *Engineer*, Jan. 27, 1888.
- Engines, Triple-Expansion of S. S. "Courier."** Brief description, with two-page plate, giving two perspective views of the triple expansion engines of the Steamship "Courier." *Engineering*, Jan. 6, 1888.
- Engineering, Review of for 1887.** A long editorial in *Engineer* for Jan. 6, 1888, gives a good review of the engineering progress and practice for the year of 1887.
- , **Estimates, Costs, Accounts, &c.** A series for young engineers showing the methods of making estimates, etc., with a discussion of the underlying principles. *Mech. World*, Jan. 6, 1887.
- Firearms, Development of Automatic.** Gives a two-page plate, and short description, of the details of the Maxim gun. *Engineering*, Jan. 27, 1888.
- Furnace, Blast, Charges.** By R. H. Richards and R. W. Lodge. Before the Duluth meeting of the American Institute of Mining Engineers. Gives experiments, illustrating the descent of charges in an iron blast furnace. *Engineering*, Jan. 20, 1888.
- Gas, Water.** An article reprinted from *Industries*, giving analyses of the various forms of water gas. Describes the plant most generally used, chemical reactions, etc. *Amer. Manufacturer*, Feb. 10, 1888.
- Gauges, Recording Pressure.** By Chas. A. Hague. Before the Minneapolis meeting of the American Water-Works Association. Discusses the uses and advantages of recording pressure gauges in water-works. *Proc. Seventh An. Meet. Am. Water-Works Assoc.*, pp. 24-31; *Am. Engr.*, Feb. 8 and 15, 1888.
- Girders, Plate, Calculation of.** By A. Münster. Gives results of investigations as to the reliability of formulas in use for calculating the flange stresses in plate girders. Presents three new formulas. Gives table showing moments of resistance as compared by different formulas. *Jour. Assoc. Engin. Soc.*, February, 1888, pp. 55-58.
- Harbor and Waterways, National Bureau of.** Gives text of bill recently introduced into the Senate by Senator Collum, Ill., to establish a National Bureau of Harbor and Waterways. *Engin. and Build. Rec.*, Jan. 28, 1888.
- Heating and Ventilating Workshops.** By John Waker. Gives details of the system of hot air heating applied to some shops in Cleveland. Illustrated. *Jour. Assoc. Eng. Soc.*, Vol. VII., pp. 1-5 (January, 1888).
- Heating, Steam.** By Chas. E. Jones. Describes the plant in use at Washington University and shows the work it is doing, also gives experience with underground pipes and smokeless furnaces. *Jour. Assoc. Engr. Soc.*, January, 1888, pp. 14-22.
- Locomotive, Mogul Freight, D., L. & W. R. R.** Gives short description, with elevations and cross-sections, and dimensions of a freight engine, of the Mogul type, for the Delaware, Lackawanna & Western Railroad. *R. R. Gazette*, Feb. 3, 1888.
- , **Passenger, C., B. & Q.** Gives a description, with drawings, showing sectional elevation, half-plan and eight half-section of a heavy passenger engine, Mogul type, weighing 110,000 lbs., for the C., B. & Q. Railroad. *Mast Mechanic*, February, 1888.
- , **Strong.** A brief description of the Strong locomotive, illustrated, with reasons for the peculiar features in its design. By George S. Strong. Also a summary of the results of trials of the engine on the Lehigh Valley Railroad, made by E. D. Leavitt. *The Journal of the Franklin Institute*, February, 1888.

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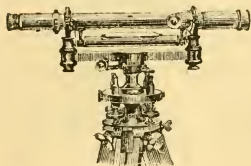
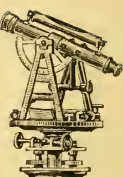


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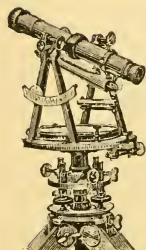
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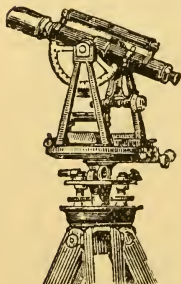
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- Masonry and Stone Cutting.** By Law. Harvey. A series of articles giving instruction in the draughting of details of masonry. *Build. News*, Dec. 11 *et seq.*, 1887.
- Motor, Parson's Steam Turbine.** Gives description with results of the practical working of Parson's steam turbine. The best results so far attained are a consumption of 52 pounds of steam an hour for each electric horse-power with steam at 90 pounds pressure above the atmosphere. *Engineering*, Jan. 13, 1888; *Sci. Am. Sup.*, Feb. 11, 1887.
- Municipal Engineer and the Management of his Office.** By R. Schreiner. Gives good hints relative to the management of the offices of city engineers. *Jour. Assoc. Engr. Soc.*, January, 1888, pp. 9-12.
- Pier, Marine Park, Boston.** Short description, with full detail drawings, of the iron pier at Marine Park, Boston. It has twelve spans, 60 feet each, resting on cast-iron pins filled with concrete. *Engin. and Build. Rec.*, Jan. 28, 1888.
- Pneumatic Foundation of a Tidal Basin Entrance Lock, at Dieppe, France.** Under over 55 feet head of water; area of caisson, about 120 feet by 115 feet. *Annales des P. and C.*, November, 1887.
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- **Frogs and Safety Switches.** By Geo. Richards, before the New England Railroad Club. Discusses the development of switches and frogs, and gives the qualities of a good safety switch. *Master Mechanic*, February, 1888.
- **Frogs and Switches.** By W. F. Ellis, before the January meeting New England Railroad Club. Discusses and advocates the use of spring-rail frogs. Discusses safety switches and advocates the split or point switch. *Mast. Mechanic*, Feb., 1888.
- **Interlocking Apparatus, L. I. R. R.** Gives a brief description with illustrated details of the interlocking apparatus on the Long Island Railroad. *R. R. Gazette*, Feb. 10, 1888.
- **Locomotive and Car Shops, C., St. P. & K. C. R.R.** Give general and detailed plans of the locomotive and car shops of the Chicago, St. Paul and Kansas City Railroad at St. Paul. *R. R. Gazette*, Feb. 10, 1888.
- **Pacific, and the Government.** Editorials showing how the present difficulties have arisen, and examines the plans proposed for their salvation. *R. R. Gazette*, Jan. 27 *et seq.*, 1887.
- **Relative Cost of Transporting Car-loads and Less than Car-load Lots.** Gives the testimony of Mr. Fink before Inter-State Commerce Commission. Submitted a statement based upon statistics. A valuable paper. *R. R. Gazette*, Feb. 3, 1888.
- **Swedish.** By W. Koersner. Treats of the railroads of Europe, but more especially with the development of the railroads in Sweden. Maps and tables of revenues, etc. *Engineering*, Jan. 6, 1888.
- Railway on Suspended Cables.** *Annales des P. and C.*, November, 1887.
- Sewers, Flow of Air in.** Gives details of experiments by W. E. McClintock on the flow of air in pipe sewers, and its effect on traps at the foot of soil-pipe. *Engr. and Build. Record*, Feb. 11, 1888.
- Ships, Tonnage of.** A good review of the use of the terms ton and tonnage as employed in maritime commercial transactions. *Engineer*, Dec. 30, 1887.
- Ship Transfer.** *Present Aspect of the Problem of American Inter-Ocean Ship Transfer.* Read before the Engineers' Club of St. Louis, March 2, 1887, by Robert Moore. A complete and interesting exposition of the subject. *Journ. Assoc. of Eng. Soc.*, February, 1888.

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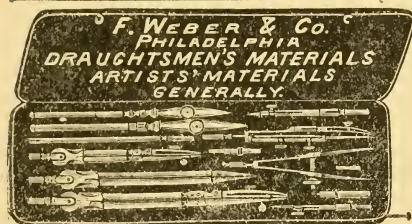
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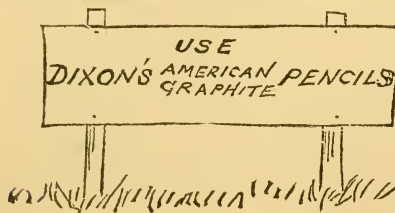
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- Steel, Its Properties, Its use in Structures and Heavy Guns.** By Wm. Metcalf, before the American Society of Civil Engineers. A valuable contribution on steel, and a plea for the Rodman gun. Discussion covering 90 pages. *Trans. Am. Soc. C. E.*, Vol. XVI., pp. 283-389. June, 1887. Abstracted in *R.R. Gazette* March 18, 1887; *R.R. and Eng. Jour.*, April, 1887; *Am. Engineer*, April 6 and 13, 1887.
- , *Open-Hearth for Boilermaking.* By H. Goodall, before the Institution of Civil Engineers. The paper gives the experience of the author in the use of open hearth steel for boilermaking since 1875, and describes numerous experiments to ascertain the cause of difficulties met with in working the plates. Abstract in *Engineering*, Jan. 13, 1888.
- , *Tests of the New Direct Process Open Hearth.* Gives results of tests made by G. H. Thomson of the new direct process open-hearth steel, of the Carbon Iron Co. made at the shops of the Union Bridge Co. It stood severe tests, and bids fair to become an important production. *Engin. News*, Jan. 21, 1888.
- Strains in Iron and Steel, Permissible.** *Annales des P. and C.*, December, 1887.
- Struts, Stiffness of.** Gives results of experiments made at Mason College to investigate the influences of variation of load, of length, and of eccentricity of thrust from centre of end section. *Engineer*, Jan. 6, 1888.
- Surveying, Use of Stadia in Railroad.** By J. B. Johnson. A series of articles showing how the stadia rods may be used with advantage in preliminary railroad surveys. *R. R. Gazette*, Feb. 3 et seq., 1888.
- Switchback Stamped, N. P. R. R.** By H. S. Huson. Gives reasons for its construction, and details of location, track and locomotives, etc. *R. R. Gazette*, Feb. 3, 1888.
- Testing Machine, Cement.** Drawings of the cement testing machine in use at Poughkeepsie bridge. *Engr. and Build. Rec.*, Jan. 21, 1888.
- Torpedo, Howell's.** Gives a full comparison of the Howell with the Whitehead and Brennan torpedo. Shows the Howell to be the best. *Engineering*, Jan. 20, 1888.
- Torpedo Boat, "Fatun."** A brief description of the station torpedo boat "Fatun," with two-page showing plans, elevations and cross-sections. *Engineering*, Jan. 20, 1888.
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- Water, Action of Boston, on Service Pipes.** By Wm. R. Nichols and L. K. Russell. Gives details of experiments made to discover the amount of zinc taken up from galvanized iron water pipes. Results show that the zinc coating is slowly but continuously dissolved. *Jour. Assoc. Engin. Soc.*, January, 1888, pp. 12-14.
- , *Mississippi River.* Abstract from the report of Dr. Charles Smart, giving the result of a series of analyses made for the State Board of Health of Minnesota, of the waters of the Mississippi River and some of its tributaries. *Engin. and Build. Record*.
- Water Analysis for Railroads.** A paper by George Gibbs before January meeting Western Railroad Club. Discusses the subject from a practical standpoint and gives the experience of the C., M. & St. P. R. R. Gives method of gathering data, results of analysis, etc. *Master Mechanic*, Feb., 1888.
- Wood Pulp Vulcanization.** By M. L. Deering. Describes a new method of treating fibrous material. *Jour. Assoc. Engin. Soc.*, Feb., 1888, pp. 52-55.

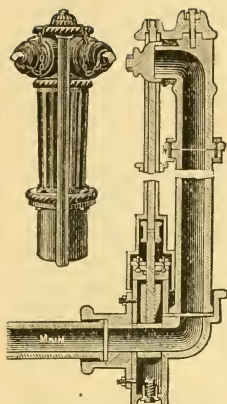
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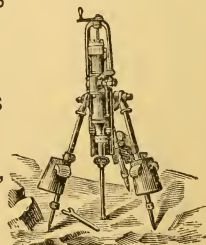
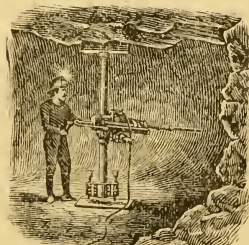
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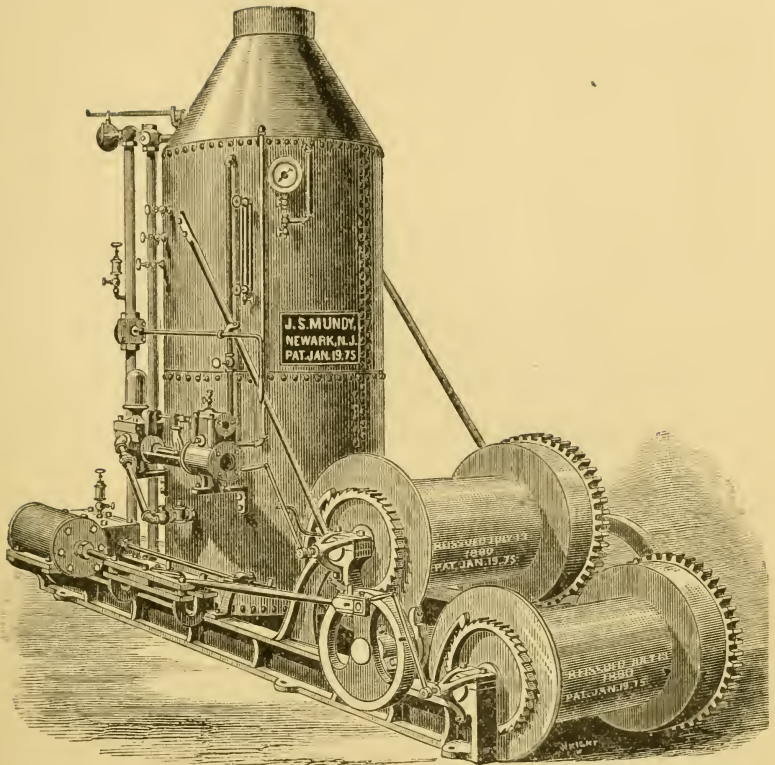
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RACINE WATER-WORKS.

BY GEORGE A. ELLIS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 21, 1887.]

Racine, Wis., is situated on the west shore of Lake Michigan, sixty-two miles north of Chicago, and is reached by either the Chicago & Northwestern or the Chicago, Milwaukee & St. Paul. It has a population of 20,000, and its principal industries are the manufacture of threshing machines, agricultural implements, wagons, carriages and the goods required by allied interests; there are also woolen and rubber factories, while the receipt of lumber by vessel from the northern and eastern shores of the lake, for shipment by rail to the west and southwest, gives a busy look to its wharves and railway yards. Situated between Chicago & Milwaukee, Racine has not a large agricultural district for its commercial support, but is more like a New England city, depending upon its manufacturing interests for its growth.

Up to 1886, dug and artesian wells and cisterns supplied all water used for domestic purposes, and nearly all required for fire protection. In the spring of that year a contract was made with the Racine Water Company to furnish Lake Michigan water for these purposes, the intake to be located a mile and a quarter from shore, in forty feet of water. The works as completed consist of about $1\frac{1}{2}$ miles 24-inch suction main, $31\frac{1}{2}$ miles of force and distribution pipe, besides hydrant connections and blow offs, making about 34 miles in the system, with which are connected 310 fire hydrants and 335 gates. The smallest distribution pipe is six inches in diameter. There are three river crossings of 24-inch, 20-inch, and 8-inch cast-iron pipe, of which the first two are laid in a trench 22 feet, and the last 18 feet below the surface of the river. There is a standpipe 25×90 feet, rising 200 feet above the lake, while water is raised by two Blake duplex pumping engines of an easy aggregate capa-

city of $4\frac{1}{2}$ million gallons per 24 hours. One of these engines is compound and one high pressure, and both are connected with independent condensers, air pumps and heater, so arranged as to exhaust to either the

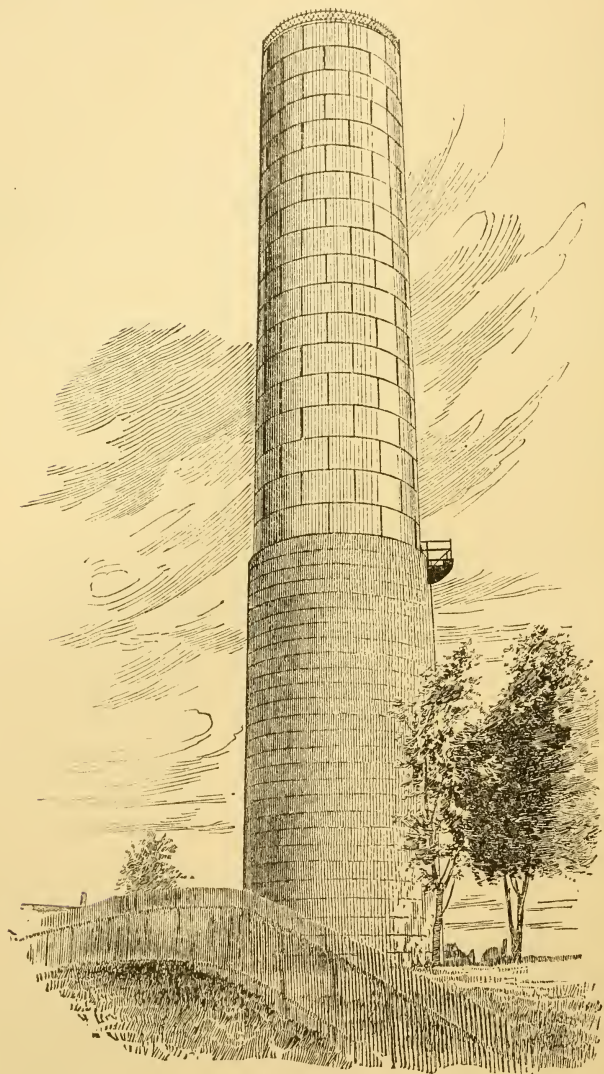


Fig. 1'

condenser or atmosphere through the heater, or to the atmosphere direct. Power is supplied by a battery of four boilers, each 16 feet long, 72 inches in diameter, with ninety-two $3\frac{1}{2}$ -inch tubes. Chimney is 100 feet high with flue 5 feet square. Boilers are fed by two No. 4 Blake boiler feed

pumps, drawing their water from either the hot or supply well, while connection is also made with the force main, and each boiler is fitted with a Hancock inspirator connected with supply well. Having thus briefly described the works as a whole, a more minute description of a few details of construction may be of interest.

Foundation and Pedestal for Standpipe.

The highest elevation within city limits is 55 feet above the lake. An elevation of 200 feet was desired for top of tank, and as all water contained below tops of the highest buildings is of very little practical value in a city where street pressure is depended upon to do all the work, the tank was set 55 feet above the original surface of the ground, or 110 feet above lake datum, upon a foundation and pedestal of beton carried to this height.

Of this structure (Fig. 1) the following are the principal dimensions : Depth of foundation below original surface, 7 feet ; diameter at base, 37 feet ; of shaft or pedestal, $26\frac{1}{2}$ feet ; height of same, 55 feet ; in plan $10\frac{1}{2}$ feet of core, hollow annular ring 4 feet, solid outside ring 4 feet ; total, $26\frac{1}{2}$ feet ; height of beton above base 62 feet. Allowing 130 pounds to the cubic foot, the weight of concrete is 4,212,000 pounds, of the tank and water 2,874,000 pounds, a total of 7,086,000 pounds, giving a pressure of 3.3 tons per square foot of underlying earth. This earth is a very tenacious clayey hard-pan, fairly dry and well drained by its natural position, though no pains was taken to lead ground water away from the base. The first five courses were each 18 inches in height and stepped back 1 foot each to the last or fifth, on which started the pedestal proper ; below this point and for 18 inches above, the entire base was solid ; the core then retreated by steps of 1 foot rise and tread to the size designated, thus distributing the load pretty uniformly over the entire base. At 19, 37 and 55 feet above the ground the core and external ring were joined and bonded together by semi-circular arches and floors, the latter two feet thick at crown of arch, except the upper floor, which was four feet at same point. Sixteen 1-inch round iron clamps were imbedded in each floor from near external surface to within about a foot of centre of core, to increase the tensile strength bonding the floors, in case of any settlement.

The material used in construction was Saylor's American Portland cement and lake beach sand and gravel, properly screened, mixed dry, in proportion of one of cement to nine of sand and gravel ; the latter graded on the beach by a cheap rotary screen of wire cloth, of three different meshes, supported on a light frame-work of iron and run by a small portable steam engine. The sand and gravel were mixed in those proportions which gave the least volume of voids, though the proportions of different grades of gravel were varied slightly from time to time to best utilize the product of the screen. The sand and gravel were hauled about $1\frac{1}{2}$ miles to site of stand-pipe, where they were stored in bins beside the mixing platform. This platform was about 16 feet square and of the right height to feed into power mixer. This mixer consisted of an iron shaft about 4 inches in diameter, with steel paddles about $2\frac{1}{2} \times 3\frac{1}{2}$ inches arranged spirally around it, their faces set at such an angle as to push the material toward the elevator end of shaft. The shaft and paddles were

enclosed in a boiler plate cylinder about 8 feet long and of slightly greater diameter than the outside of paddles, flanged on each side for convenience in opening, and mounted in a heavy oak frame. On one end of shaft was a large gear, connected with a smaller one on counter shaft and pulley, with belt to an 8 h. p. portable steam engine. At the other end of shaft, which was extended some distance beyond cylinder, for purposes of clearance, was attached a small gear wheel, connecting with elevator, running in cast-iron boot below and at end of cylinder.

The elevator was composed of a chain of malleable iron links, with cast-iron buckets, running on sprocket wheels above and below. The buckets were at first set every third link, or a little more than a foot apart, but as these interfered with each other in discharging over the upper wheel, and as the rate of motion to discharge of mixer was ample, every other bucket was removed. With the progress of the work the framework and upper wheel were raised and the chain lengthened as required. The mortar thus raised and discharged like grain, a further similarity suggested itself of carrying the frame and upper wheel sufficiently high to discharge through swinging spouts upon that portion of the work desired. It was found, however, that the finer material would lodge and stick without provocation, choking the spout, while the larger material, pebbles and stone, would run away from the finer, and no matter how thoroughly mixed it left the mixer, it reached the work as if it had again passed through the screens. After trying various sizes of spouts at different angles of elevation, and with the mortar at different degrees of moisture, the spout was abandoned and a platform built at such height below the upper sprocket wheel that the buckets discharged directly into wheelbarrows, in which the material was wheeled from the platform on runs and dumped where wanted. There were two beds upon the mixing platform, each holding "one batch" or ten barrels of dry material. After delivery into beds, which was done in layers, it was twice turned over dry, then wet according to condition of material and temperature of atmosphere, the standard being "all the water possible without the concrete becoming shaky under thorough tamping." This usually leaves the mixture so dry that one unaccustomed would be afraid to use it, but really of the degree of moisture susceptible of the most complete tamping. After wetting the material was again turned and then delivered into the mixer, from which it issued with the cement, sand and gravel, thoroughly incorporated in one mass.

The outside of pedestal was composed of sand and cement, "two to one," mixed by hand to the same degree of moisture as the interior, and filled in against the mould and submitted to a separate and combined tamping, so that it formed a part of the entire mass, and in no sense an outside skin that might peel off. The material was deposited in layers about six inches thick and tamped as fast as delivered, with cast-iron rammers five inches square, weighing about ten pounds each. The molds for the different surfaces were constructed of narrow sheathing, 2 feet 6 inches long, nailed vertically to ribs cut to the proper circle; the outer molds being held in place between eight uprights, 6 by 8 inches each, of 2-inch plank, 8 inches wide, with broken joints, for convenience of extension. These uprights were held in place by $\frac{1}{4}$ -inch rods,

with thread, washer and nut on each end, so as to preserve the correct form, size and vertical line. The rods were threaded through short pieces of wrought-iron pipe of the same length as the thicknesses of concrete, so that they could be easily removed upon completion of the work. The molds were secured or slacked by use of wedges. At their top (on the outside) and 2 feet below were fastened triangular strips ($\frac{3}{4}$ by $\frac{3}{4}$ inch), which gave the exterior the appearance of being laid in blocks.

Nearly three months elapsed from commencement of foundation to completion of pedestal, 1,610 barrels of cement were used, and the concrete measured 1,200 cubic yards in place; the entire cost, including screening, hauling, machinery, tools, stagings, carpenter work, and all expenses was not far from ten dollars per cubic yard. The only criticism upon machinery is that working material so dry, it set and adhered to shaft, cylinder and buckets, so as to require cleaning nearly daily, with a continual charge for renewal of paddles.

Two questions will naturally arise with engineers regarding this work, viz., expediency and durability. The first, each man will have to decide for himself; circumstances might make the cost of such a structure more or less than in this instance, where the cost of cement delivered on the ground was about 36 per cent. of the gross cost. As to durability, the last concrete was put in place late in September; from then till the completion of tank, about middle of January, the interior was open and equally with the outside exposed to the air, the temperature falling to 22 degrees below zero, thus insuring the penetration of frost entirely through the structure.

When the tank was first filled one or two overflows (before the exact relation of the particular gauge used to the top of the tank had been determined) nearly covered the exterior with a sheet of ice. Yet notwithstanding the comparative greenness of the mortar, the admission of such intense cold to the interior, and the severe experience of the outside, which certainly is not likely to be exceeded, there has been this summer no perceptible flaking and every grain of sand on both the outer and inner surfaces stands out as sharply and resists removal more strongly than on the day the molds were first removed. With this experience, even though the time elapsed has been so short, the structure seems likely to be as durable as if built in any other form of masonry.

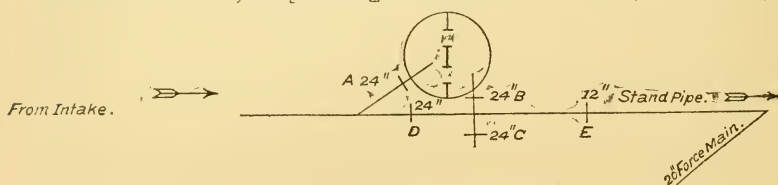
Electric Valve.

There are two pipes leading to stand pipe through hollow annular ring of pedestal, one of 10 inches diameter for purposes of supply, and a 16-inch, with check valve, for return flow. In several instances one pipe only has been used for both inflow and outflow, with a balanced check-valve, closed by a certain velocity of the inflow. This form, though undoubtedly the more convenient, is open to the objection that the full speed of the pumps cannot be utilized in filling the tank. An ordinary valve was therefore inserted in the 10-inch supply pipe, and connected with pulleys and weights, very much after the manner of a fire-alarm striking apparatus. By throwing an electric switch at the pumping station a magnet releases a pawl holding the weights and allows them to fall, closing the gate in about $1\frac{1}{2}$ minutes, though this speed can be

varied if thought desirable. If the pumping ceases, the check valve opens and gives stand pipe pressure, but no water can be forced into the tank till the 10-inch valve has been opened by rewinding the weights. This delay may sometimes be awkward, but the action is positive, and will not interfere with any action of the pumps unless desired.

Pump Well and Connection with Lake Pipe.

By the terms of the contract with the city, the intake was to be laid in a trench 10 feet below the bed of the lake. This required the shore pipe to be laid equally deep at the water line, while as the lake fluctuation between high and low water is about 2 feet, in order to insure the suction pipes being always submerged, the trench at the pump well was excavated 4 feet below ordinary lake level. The material for this distance, about 400 feet, is firm beach sand and some pebbles, in which the water stands at same height as lake. As the lake trench had to be made by dredging, exposed to the storm and so requiring a broad surface excavation, the coffer dam for the shore pipe was carried out into $2\frac{1}{2}$ feet of water, or the necessary depth below water line at that point was $12\frac{1}{2}$ feet. For the first 50 feet, the sheeting used was 6×10 inches, 16 feet long ;



then 150 feet of 4×10 inch, and the balance 3×10 inch, all grooved and splined in proportion to thickness, and driven to the underlying clay, from 14 to 11 feet below water line, except the upper end of trench, where a shorter plank was used. The sand was so fine it was impossible to drive the sheeting by a hammer; use was therefore made of two jets of water from a steam pump on pile driver. The water pressure usually carried was about 50 pounds; size of jets $\frac{3}{4}$ inch. These were attached to poles and pushed down beside of and with the sheeting, much care being required to carry the jets equally on each side; as if one side was washed clear faster than the other, a crowding followed, which would sometimes split the splines. Each piece was held in place in guides quite tightly, so that often a light blow from the hammer was necessary to overcome the friction in the ways, but usually the weight of the hammer was sufficient to the clay, when a few blows fastened the point in place.

Water was pumped out of the coffer-dam by a centrifugal pump with 10-inch suction and 8 inch discharge. The pump well was situated in line with the forward end of the pumps, was 14 feet interior diameter, $14\frac{1}{2}$ feet deep below the lowest water, with a bed or floor of concrete 2 feet thick. A wall with screens divided the well into two parts. The intake and suction pipes were each fitted with quarter turns and carried down to 2 feet above the floor, where they were supported on iron framework resting on the floor. We will note in passing that at the test the combined pumps and condensers were unable to lower the water in the well to less than 8 feet upon the floor. The above sketch shows arrangement of pipes, gates and by-pass.

At pump-well, as ordinarily used, the gates *D* and *E* are closed, and *A*, *B*, *C* open, the water flowing into the well at *A*, passing through the screens and out at *B*. If it is desired to draft from the intake direct, the gates *A* and *B* are closed and *D* opened; under this arrangement the well can be examined or cleaned. If anchor ice or other obstruction gathers at crib, by closing *A*, *B* and *C* and opening *D* and *E*, the standpipe head of 200 feet is thrown upon the intake through a 12-inch pipe connecting the force main with the cross in suction pipe.

Intake Pipe and River Crossings.

Although one is suction and the other force main, the method of laying is similar, and a description of one answers for both. This work was designed and executed by Messrs. Thacher & Breyman, of Toledo, Ohio. The intake is of 24-inch cast-iron pipe, with bell and spigot, as in street work, and was usually laid in sections of six lengths, or 72 feet. These were put together on ways carefully prepared on the dock, and the joints yarned, run and calked in the usual manner, head boards put over each end and covered with canvas securely confined around pipe. This is best shown in Fig. 3, as are also the sloping ways, adjusted and held in perfect surface by the rods passing through cap on piles in stream.

The method by which these sections are united is shown in Fig. 2. The

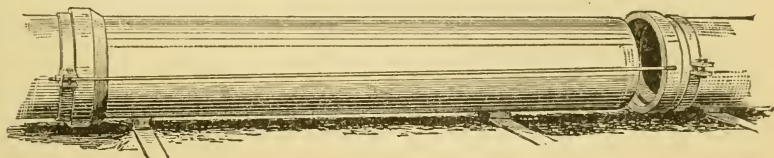


Fig. 2.

spigot length of each section is put into a lathe and the bead turned off, and the pipe turned to a taper of about one-eighth of an inch in four. These spigot lengths were all turned to a gauge, and were interchangeable. This prepared spigot was inserted in the lengths intended for section hubs, leaving an end clearance of about one inch. The joint was then yarned lightly and run, and the spigot removed. When laid, the one-inch rods on each side were passed between the bolts in ears of clamps, and on drawing up, the inch left when the joint was run allowed the hub to be drawn on to the spigot, which expanded and swedged the lead to place, giving a joint as perfect as any others in the sections. With an internal pressure, the tendency is to push the lead tighter to place, both in the lead groove and on the taper spigot. That it made a perfect joint on the 24-inch river crossing was proved by tapping and putting on a pressure gauge, then, while the pressure was at 130 pounds, shutting the gates on either side the crossing and allowing the external pressure to drop to 70 pounds. Under this severe test, which was equally a test on two 24-inch gates, the pressure gauge was several minutes dropping to the normal point.

Fig. 3 shows a section of 24-inch pipe ready for loading, and Fig. 4 floating beside the working scow. If no water passed the canvass covering, there would be a buoyancy to the section of about 40 pounds per foot; but to insure against mishaps, there are more than casks enough to float

the pipe when filled with water. The casks are especially made for this work, as the ordinary barrel will collapse if submerged much beyond 25 feet. A pair of barrels standing on the scow illustrates how the pipe is carried. There are two rings to each cask, passed under heavy hoops; the

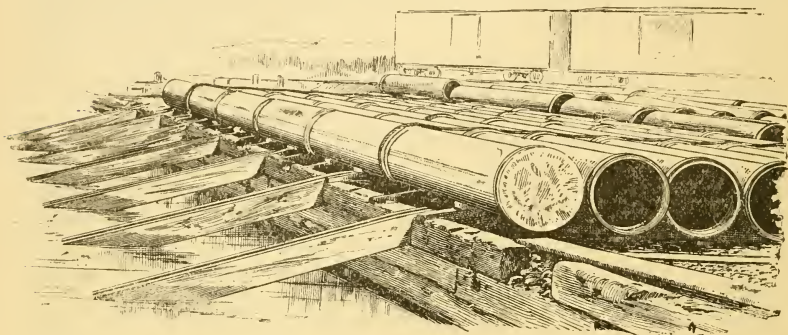


Fig. 3.

ropes are made of uniform length with loop at each end, and are secured to rings by tarred ends which are cut when the casks are released. Before towing out into the lake the casks are lashed together over the pipe to prevent their shifting in case of sufficient swell to lift some portions of the section off its saddles.

The manner of laying can be best described from Fig. 4. Arrived at the proper position in the lake, four anchors are carried out some distance

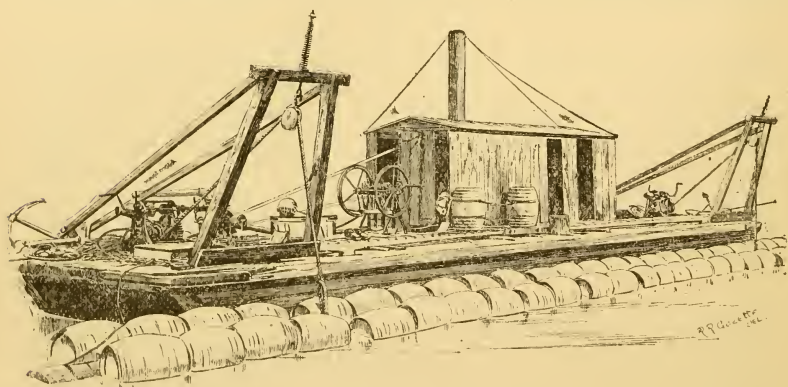


Fig. 4.

away and the scow hauled approximately to place, the pipe line being marked by buoys and ranges ashore. The diver then goes below and examines the spigot of the last section laid; if earth or mud is around it the centrifugal pump is started and a flexible suction lowered to the bottom, the lower end applied to the vicinity of the joint and the material sucked out. The pump stands so near the surface of the water that but a small lift, plus the friction in hose and pump, is all that is required to get a

powerful current. As soon as all is clear around the spigot, the headboard is removed, the section filled with water, and a sufficient number of casks cut loose to overcome the buoyancy, not more than 700 or 800 pounds usually being thrown upon the derricks; the section is then lowered ready to place, the headboard of spigot cut loose to drift above, and the section further lowered nearly to position; the section now hanging in deep water, the ropes supporting it form plumb lines and the scow is moved so that the pipe is placed accurately on line of buoys and ranges; the pipe is then lowered till the hub just touches the spigot, when the bolts are entered in the clamps and the nuts drawn tight enough to make sure of retaining the hub on spigot; the outer end of pipe is then slacked away to within a couple of feet of the bottom. If any obstruction is met with, preventing this lowering, which is observed by knots on the falls, signal is given to the diver below and an examination is made. If the obstacle is anything which can be removed by pumping, that is resorted to; but if the solid earth shows that the excavation has never been made, then the two sections are disengaged, the pipe raised to the surface and the dredge recalled to complete the work. It is seldom, however, that this last has to be resorted to. When examination shows everything favorable, the nuts on each side are turned up as tight as possible, alternating from side to side of the pipe every ten quarter turns to preserve an equal strain. When all is drawn taut, the outer end is slacked entirely away and further examination is made. If the section is found properly resting on the bottom, the lashings are cut which hold the casks in place and they rise rapidly to the surface, sometimes jumping two feet out of water; occasionally the pipe will bear so heavily on the bottom that the buoyancy of one cask is not sufficient to draw the ropes from underneath, in which case the lashing is cut on the other side and the rope left at the bottom. The best day's work was made in June of this year, when four sections, or 288 feet, were laid in one day, the depth at that time exceeding 45 feet of water.

Connection was made with the shore end last December by cutting through the coffer dam and pushing through a short section with a head on it. The dam was then made tight around the pipe and the coffer dam pumped out, when the two ends were brought within about eight inches of each other, and carefully placed for line and grade; a flanged sleeve was then made, about two feet long, with a projecting rib four inches from each end, the head board removed and the sleeve put in place under water, and the joints partly calked with lead pipe, but owing to the severity of the weather (below zero), the coffer dam was again pumped out and the calking finished in open air.

Upon the completion of the intake this summer, a tee and upright 8 feet above the bed of the lake was placed at the end, and this surrounded by a submerged crib, 18 feet square on the base and 10 feet high, in nine compartments, the centre one of which surrounded the upright. The timbers forming this crib were halved and doweled solid together, except the upper three courses, which were left 2 inches apart, the top was covered with timbers and plank except the centre, which was covered with boiler plate punched with 1-inch holes. The crib was filled with sufficient stone to sink it while buoyed up with casks in the same man-

ner as the pipe, when it was lowered and surrounded with 50 cords of stone. It was after this was all completed that the test of well referred to was made.

DISCUSSION.

Mr. M. M. TIDD : I had occasion to examine these works recently in a professional way. At Milwaukee an additional pipe was being laid out into the lake to increase the supply. This was being done by Mr. Breyman, the party who laid that at Racine. The work was temporarily suspended while I was there, on account of a severe gale from the northeast, with a heavy sea. I saw the pipe, and Mr. Breyman explained the operation. The joint is similar to the English turned and bored one, only that space is left for lead. The joint, after being run, is drawn hard together with side screw bolts, drawn through clamps. The joint is 7 or 8 inches in depth, as used at Milwaukee, and 4 inches at Racine. There were several sections on the shore at Milwaukee when I was there.

Mr. F. L. FULLER : Was the lead run and then driven up?

Mr. TIDD : On the intermediate joints of the section, yes ; on the special joint, no.

Mr. FRED. BROOKS : I should think the success would depend largely upon the diver.

Mr. TIDD : It does, and in that lies the main objection, for my experience with divers has given me very little confidence in their integrity.

The test, however, in this case showed the work to be well done.

One of the difficulties with which the company had to contend was that the city government (Racine) insisted that the intake pipe should be laid 10 feet below the bottom of the lake for its entire length, so that in 40 feet of water at the outer end the pipe was 50 feet below the surface of the lake. It is difficult to handle sections of pipe over a certain length with the joints made up without creating leaks.

I remember laying a 16-inch flange pipe 120 feet long in the water. This one I hung up in slings and lowered in with screws. Possibly I might have succeeded with a longer one, but I am not sure of it. I found that when suspended it would admit of a torsional movement of 4 inches. This was, of course, elasticity of the cast-iron.

Possibly it might have endured more, but I did not think it prudent to try it.

In relation to the concrete foundation of the stand-pipe, I have examined it very carefully. I was there when they had a cold snap this winter. They run it over occasionally ; had done so the day I saw it ; the cement is sound and perfectly hard.

Mr. HENRY MANLEY : It seems to me that the method of laying this pipe is a very ingenious one. To show the progress that has been made in this kind of pipe laying, I will say that a 20-inch pipe was laid from Chelsea to East Boston in 1850, which is still in use. This pipe has a joint movable in a longitudinal, vertical plane, made by laying two quarter turns about every 30 feet. The joint is made by a wide flange on one pipe and a narrower one on the other, with a cap ring with rubber packing covering the narrow flange and bolted to the wide one. This pipe was put together and lowered into a trench from false works.

In 1870 a leak was discovered in deep water in this pipe and a new 24-inch pipe was laid, which also has a flexible joint. This is a butt joint, only movable vertically. The pipes are held together by links and trunnions. The whole line of pipe (about 200 feet) was put together on the flats, buoyed with barrels and floated to place. It was a difficult undertaking, and at least three attempts were made before it was laid. I remember one curious omission in the design. Lugs were cast on the tops of the pipes to prevent too great motion in the pipe from opening the joints on the bottom, but no provision was made against the pipe opening on the top. When it was well afloat the motion of the waves opened the joints at the top and it went spouting like a school of whales. The leak in the old pipe was mended with pine wedges, a rubber patch and screw clamps.

In 1871, Mr. John F. Ward laid two 8-inch ball and socket pipes from Point Shirley to Deer Island. These pipes were laid by using a horse windlass on the further side, joining a few pieces of pipe, starting up the horse, adding pipe, and starting up the horse again, till all was laid. I think both lines, each about 300 feet long, were laid between noon and midnight. I remember staying on the ground till late at night, as the tide served best then for the work.

EFFECT OF LOW TEMPERATURE ON PORTLAND CEMENT CONCRETE.

By P. M. BRUNER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read December 7th, 1887.]

It happens not unfrequently that engineering constructions with concrete have to be carried on at low temperatures. It is desirable, therefore, that the engineer who is not an expert in the use of cement should still be able to judge when and to what extent such construction can be carried on. Published examples of concrete construction at low temperatures with alleged success may be more puzzling than they would have been if they had turned out failures. With a view of forming a basis for a better understanding of this question the following propositions will be made and considered:

1. At or below a temperature of 32 degrees F., the process of setting of cement is practically if not absolutely suspended.
2. The injury done to concrete by freezing is almost wholly due to the expansion of the water used in mixing it.
3. Whatever will counteract or limit the expansion or control the freezing will to that extent counteract, limit or control the injurious effect of low temperature on concrete construction.

The first point, "that the setting of concrete is suspended at or below 32 degrees F." may perhaps also be stated in this form, "that the tendency of water to crystallize, due to the chemical action of the cement, is overcome by the tendency to crystallize under the influence of low temperature." Whether the suspension of setting is due to the crystallization or to a low temperature, independent of congelment,

has not been determined, nor is it known whether the setting is wholly suspended, and if so, at what temperature this total suspension begins. The following experiment seems, however, to make it clear that it is possible to expose fresh concrete to low temperatures without apparent injury. Ten test samples were made; five of these were left 24 hours in a room of which the temperature was 40 degrees F.; they were then placed in water, the other five samples were immediately placed out of doors and exposed for 48 hours to a temperature of -10 to -6 degrees F., and then brought to a room of which the temperature was 40 degrees F.; they thawed out in a few hours, became almost as soft as when first made, and at the end of 24 hours had set; they were then placed in water with the former five tests; at the end of a couple of months all of the ten tests had the same tensile strength.

Secondly, that the injury to concrete by freezing is almost wholly due to the expansion of the mass, follows in a great measure from the fact that the setting is simply suspended. This leaves the swelling and loosening of the mass as the only cause of deterioration. It happens frequently that artificial stones and paving blocks get injured by sudden cold spells. The injury shows itself in blisters on the surface and by cracks more or less deep. The damage is confined generally to these injuries, for the parts unaffected remain so and cannot be distinguished from work not exposed to frost. Concrete paving blocks laid late in the season three years ago froze badly during the following night, the next morning the blocks were a mass of blisters that could be lifted off, and along the edges were long cracks running parallel with the exposed sides, after noon the frost had thawed out and the blocks were worked down with trowels until they looked about the same as when first made. These blocks exposed to the severest kind of usage stones can be put to for three years show themselves equal to any work of its kind. The damage done by the frost was simply that of loosening, or displacement; this being remedied the blocks were uninjured.

Thirdly, whatever will counteract or limit the expansion or control the freezing will to that extent counteract, limit, or control the injurious effect of freezing on fresh concrete. By counteracting the expansion is meant any means of bringing the mass to its proper volume during the thawing out or immediately thereafter. In the case of the paving blocks just stated the counteracting consisted in pressing or rubbing the particles back into place. In constructing concrete piers or large masses the weight of the mass might effect the same. Brick walls are laid with hot mortar which freezes immediately after it is placed in the wall. With moderation of temperature the mortar softens, the wall settles and the mortar sets. By limiting expansion is meant a limitation of the quantity of water used in making concrete, or a provision for the draining off of any excess as rapidly as possible. Be it remembered that it is the water that freezes rather than the concrete as a mass. The expansion can therefore be limited by limiting the use of that which brings about the expansion. Any one failing to confirm the experiment with the ten test samples above mentioned would probably find the cause of the failure in not

noting this point. This point will also account for the fact that blocks of concrete made earlier in the day will escape injury by frost, while those made in the evening will be injured.

Where the expansion cannot be sufficiently counteracted or limited, and where the concrete cannot be properly mixed on account of the cold weather, there still remains one method, that of controlling the freezing. We can lower the freezing point of the water by adding some neutral substance. The most available perhaps is common salt, and this lowers the freezing point of water about 1 degree F. for each per cent. by weight added to the water. A series of experiments made for the purpose of indicating the propriety of its use with regard to its effect on the cement shows that up to the limit of the saturation of water no harm results from its use. This is in part accounted for by the fact that plasticity is obtained with less of the solution than with water alone.

The consideration of this subject might be extended further into details, but the engineer noting the principles illustrated above will no doubt be able to account for all failures in practice.

CONSTRUCTION OF RESERVOIRS AND DAM AT ATHENS, GA.

BY CHARLES H. LEDLIE, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.
[Read January 4, 1888.]

The paper I present to you to-night is a brief description of the reservoir built at Athens, Ga., in 1883.

I do not intend to go into the theory of the dam, beyond stating that the safety factor was five and its stability was calculated by moments.

The source of the water is springs at the head of the valley and their flow was measured by a weir and calculated by the following formula :

$$Q = 3.33 (L - 0.2 h) h^{\frac{3}{2}}$$

Q = Cubic feet per second ; L = length of weir in feet ; h = depth of water flowing over weir in inches.

The reservoir is located at the mouth of a small valley about a mile long enclosed by low hills. The character of the materials, the sudden disappearance of the rock in the centre, and the hill running across the head, giving the form of an amphitheatre, shows the valley must have been formed by some convulsion at an early period.

The construction was as follows : We first located the centre line of the dam and sounding along the western slope we found rock at a depth varying from three to five feet ; as we sounded down the slope and passed the bed of the creek, the rock broke abruptly off, neither was there any trace of it at a depth of fifteen feet nor for a distance of a hundred feet, when we suddenly came upon it again at a depth of six feet, and continued to find it up the east slope of the valley at a depth varying from four to six feet.

The material developed at the portion of the centre line where the rock disappeared was blue clay. This formation enabled us to tell just how deep it was necessary for the foundation of the dam to be in

order to prevent water from leaking under it, the materials we had to deal with and how to arrange them in their proper order. The materials found were soil, red and blue clay, gravel and rock. We first removed the surface soil 200 feet back from the centre line and deposited it on the back of the dam with scrapers. We then cut a trench 6 feet deep and 9 feet wide (see plate No. 3, showing foundation line), which was carried across the valley and up the east slope of the hill. On this side, half way up the hill, we found a seam running at about an angle of 60 degrees with the centre line. When the clay and loose rock had been removed to the required depth it proved to be a spring, which was stopped in the following manner: The seam was about $\frac{1}{4}$ inch wide. We had all the earth removed both ways until we passed the footings on both sides of the dam; we then put $\frac{1}{2}$ inch pine wedges in and drove them down 5 inches below the surface, and in twenty-four hours they were swollen in tight; we next had some clay kneaded up and rolls made of it with hemp centres, this was well packed in to a depth of 2 inches; on this we put $\frac{1}{2}$ inch of dry sand and then ran in one inch of lead, had it well caulked and filled up with grout made of Portland cement. We had hardly finished when a spring broke out at the very end where the run-

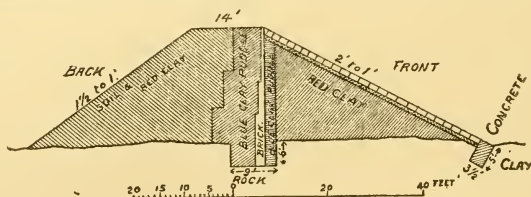


Fig. 1.—Section of Dam.

ning in of the lead was stopped, but being outside of the dam it did no damage. (The reason I used lead was that as I could get in such a small quantity of grout, it would only be a matter of a short time before the water worked its way between the rock and cement.)

The priming wall was now started so that its front face came exactly under the front angle of the top of the dam, and was built of hard brick, laid in cement of the following thickness:

Twenty inches for 2 feet, then reduced to 16 inches, from 16 inches to 12 inches, from 12 inches to 8 inches. As it was carried up, a puddle wall 2 feet thick, of blue clay, was made in front of the priming wall; the main puddle wall at the back was also made of blue clay, 5 feet 4 inches thick, until the surface of the ground was reached, when it was increased to 9 feet 4 inches thick, the puddle then being reduced in thickness as the height increased, first to 7 feet 4 inches, then to 5 feet 4 inches at the top. These two puddles were made entirely of blue clay, in 6-inch layers, and rammed into a solid mass (see Fig. 1). The back section of the dam was made of soil and red clay, mixed together and spread in 8-inch layers, wet and rammed. The front slope was made entirely of red clay, spread in 8-inch layers, and well puddled. The back slope was then carefully sodded, and the front slope covered with six inches of small broken stones and coarse gravel, rolled very hard with a 2-ton roller.

We next cut the footing for the rip rap, and put in a block of concrete $3\frac{1}{2}$ feet by 5 feet. The rip rap was carefully laid, and then a thin grout poured over the entire face and swept in all the cracks. No stones were used in the rip rap smaller than 4 inches by 10 inches by 12 inches.

The waste weir is on the east side of the dam, and built as follows: We cut down a section of the dam 4 feet below the top and put in $1\frac{1}{2}$ feet of concrete over the entire bottom of the section 10 feet wide; it was then paved with brick laid in cement and a 12-inch wall carried up on each side, with wings running out beyond the slopes of the dam. Across the back a 12-inch brick wall was built, through which runs a 20-inch waste-pipe that can be closed just before the dry season and give an additional storage of 2 feet.

During the construction the water of the creek was passed under

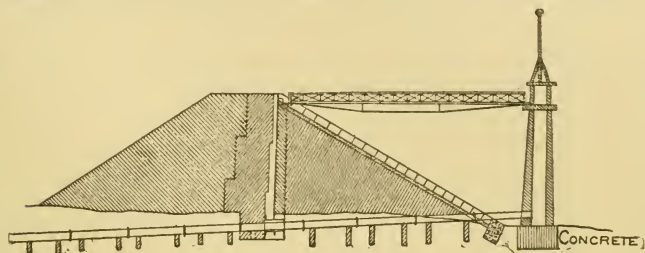


Fig. 2.—Section of Dam, Inlet Tower and Pipe.

the dam through a 20-inch pipe, and at every 8 feet on this pipe little shafts 12 inches in diameter were carried up until they came above

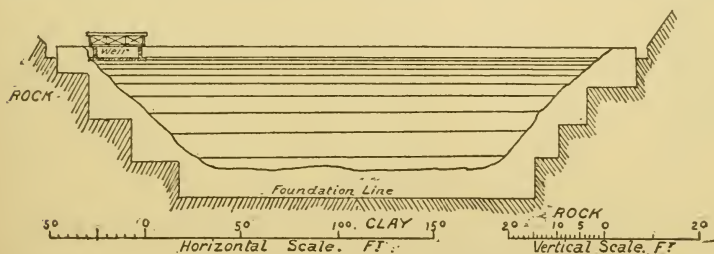


Fig. 3.—Mean Section of Reservoir.

grade; their use will be explained hereafter. The inlet tower and pipes were then put in (Fig 2), the tower being provided with a screen and slide valve (to be used in case of repair). We used a large special with three flanges 6 inches wide, through which the inlet pipe was passed and leaded in. This special was built into the brick-work of the priming wall, thus preventing the water from following the pipe, which is often the case and causes much damage.

The inlet tower is reached from the top of the dam by means of a small bridge 2 feet wide and 50 feet long. (See Fig. 4, broken line shows original surface, full line shows depth excavation was carried down; also shows section of reservoir.) Fig. 4 also shows the em-

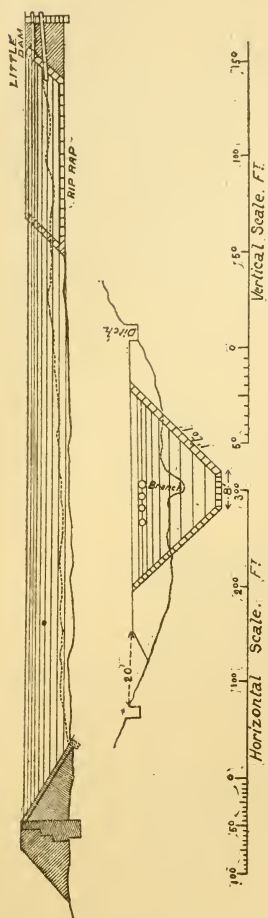


Fig. 4.—Longitudinal Section of Reservoir and Section of Neck.

bankment at head of reservoir called the neck, plainly showing the manner in which it was built. A small dam was built across the head of the neck as shown in the section of the reservoir (Plate 4 or 5). The water passed into the neck from the creek through four 6-inch pipes. Over the mouth of each pipe there was placed a screen as well as automatic valves, which are always used in rainy weather in order to keep out the muddy water. The dam at the head and neck was built to raise the creek water, so as to pass it round the reservoir in the large ditch, cut for that purpose on the west side of the hill, and to keep the water from settling back over the adjoining land. (Plate 5 shows general plan of reservoir complete.)

The reservoir is protected on all sides by storm ditches. The small dam at the head of the neck was not built until the 20-inch pipe passing under the large dam was closed. The pipe was stopped in the following manner :

A small coffer dam was made in (3) sections to fit the slope (see Fig. 6), and a good water-tight joint made around it. The water inside was then allowed to run out, and a large tarpaulin, weighed down with stone, was spread under the mouth of the pipe and carried up the sides of the coffer dam, giving a perfectly tight joint. The mouth of the pipe was closed with brick laid in

cement. Next shaft No. 1 was filled with concrete to grade (the size of the stone not to exceed $\frac{3}{4}$ inch in diameter). Shaft No. 2 was filled with sand; No. 4 was also filled with sand, and No. 3 was then run full of grout and so on until all were filled, and lastly the end of the pipe was closed with brick laid in cement.

The coffer dam was taken out after the cement had been allowed 24 hours to set, and the pipe was found to be perfectly tight. Then we built the little dam at the neck, on the same principle as the large dam. The entire bottom and sides of the reservoir were covered with white gravel to a depth of 4 inches (the gravel being found principally in pockets in the excavation and from gravel pits near by) after being spread it was rolled compactly by a two (2) ton roller. A gravel walk, 10 feet wide, was built between the storm ditches and the edge of the reservoir.

The reservoir filled in thirty days, and from fifty weir measurements I

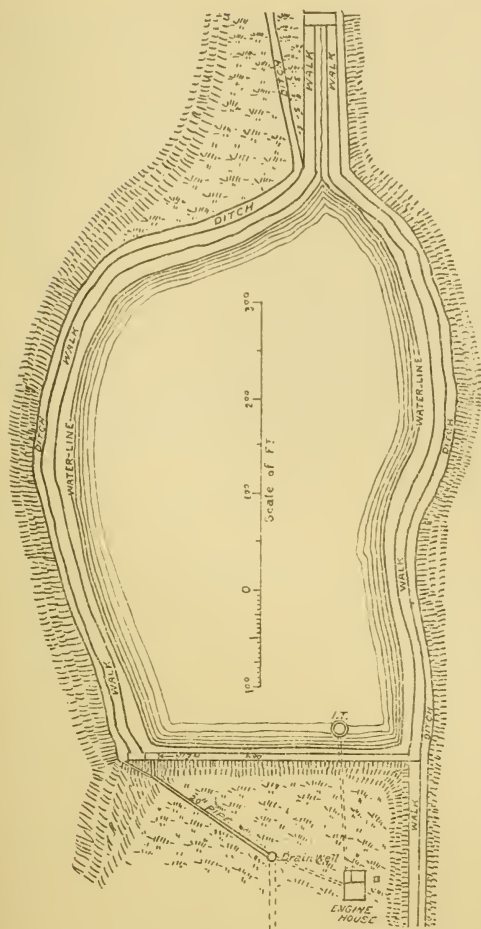


Fig. 5.—Plan of Reservoir.

once or twice in bringing their loads, considering that sufficient for making the puddle wall; and in not protecting the sides of the reservoir with storm ditches, letting the contractor put in all sizes of stones in the rip rap. A great many prominent engineers say, "priming walls of stone or brick are useless. Give a crawfish or a muskrat a few feet of soft digging and it will stop when it comes to the hard puddle," all of which is very true if the rat and crawfish have been properly educated, which is rarely the case, however. I know of two storage reservoirs in the South where the dams have broken away, one caused by muskrats and the other by crawfish; both were built by the same engineer, and on the supposition that these animals stop digging when they come to the hard clay puddle. From my own experience I offer this bit of perhaps "poor advice," wherever you have muskrats or

found the flow (the time being the fall of the year) varied from 750 thousand to 800 thousand gallons per day, giving a capacity of about 22,000,000 gallons, one million more than was originally calculated for; to which can be added two (2) feet additional storage at any time.

In closing this paper I wish to call attention to a few things that I have noticed about several storage reservoirs I have had occasion to examine of late. The designer failed in each case to carry the foundation of the puddle wall deep enough, and water leaked under the dam, in the tying in the ends, in the footing for the rip rap, in preventing the wash of the back slope from rains by sodding, in arranging the materials properly, and especially in puddling, which I have noticed the engineer trusted to doing by the passing of a heavy roller, or the tramping of cart horses over the layer

crawfish, do not leave out a priming wall: even if it is only 4 inches thick, it is better than nothing, for if you leave it out it is only a question of time before you are sorry you did so.

And one other thing before closing; I have frequently noticed that little or no attention is paid to the flow of water into a storage reservoir as regards protecting the inlets from all sorts of rubbish that comes down the stream passing in and settling into it, or of providing means of

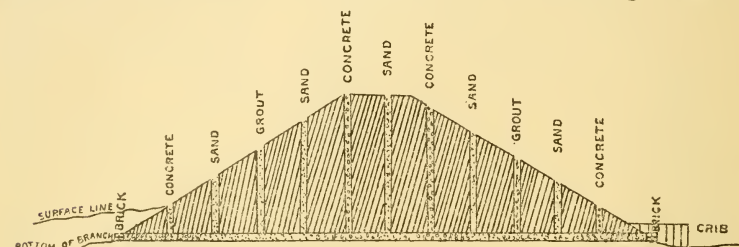


Fig. 6.—Section through Branch.

throwing this water round the reservoir when you want to clean or repair it.

I believe if engineers would pay more attention to the few points mentioned above, which are very old in practice, but sadly neglected nowadays, they would have less trouble and save themselves the mortification of other engineers going in a few years and repairing practically their new work, which has gone to pieces, for no other reason than carelessness when constructed.

A METHOD OF BUILDING A SECOND TRACK FOR SINGLE TRACK RAILROADS.

BY H. C. THOMPSON, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read August 9, 1887.]

To successfully and economically carry on a piece of railroad or other construction, the plan of operation must be carefully considered, for the better the plans are laid the closer they can be followed, and hence dispatch, comfort and economy will follow as a natural result, provided intelligent superintendence is given to the work. The question proposed to be considered in this paper is the building of an additional track to a single track railroad already in operation; and for the purpose of strengthening the points considered, we will suppose that the amount of money available is limited and it is desirable to obtain the greatest benefit from the expenditure.

1. Location. The line of the additional track should be carefully located on the ground, keeping in view improvement in alignment as well as saving in amount of earthwork to be done. And as the object to be attained is a complete double-track road with the two tracks parallel, the construction of the additional track should not necessarily be confined to the same side of the existing track, but should connect with and cross,

combining the old track with the new as chance for improvement and saving in work present. All this should be carefully considered before work is commenced.

2. Right of way. After the location is definitely determined upon, additional land for the increased roadway should be obtained wherever necessary. The most important particular under this head is the acquisition of land at the terminals, and this should receive liberal consideration. The object of an additional track being to meet both present and prospective requirements, it can be put down as a safe assertion that contiguous land at terminals will advance in price as the railroad itself increases in importance. And as it is the amount of business done by which the importance of a railroad is rated, and as the terminal points are, as a rule, where the bulk of the business is obtained, it is fair to assert that the contiguous land will advance in price with the advance in importance of the railroad. Another point under this head to consider is that no matter how well laid a railroad is, or how well its rolling stock and power is maintained, its management is helpless to operate with economy and dispatch without adequate terminal facilities; and land must be had to construct them from time to time to meet the ever increasing demand in this line.

3. Terminal facilities. Based on experience, terminal facilities should be constructed to fully meet the outside requirements of the present. This should include the removal of shops, engine houses, other buildings to points more convenient or from ground needed for other purposes: building of docks and providing them with improved appliances for handling bulk freights with dispatch and economy; re-modeling and adding to freight yards and constructing new yards for storage or otherwise to relieve other points necessarily overtaxed by reason of an enforced cramped condition.

4. Construction. The next point to consider, after having determined upon the location and the amount of improvements at the terminals, is the construction of the balance of the line. As this involves earthwork and masonry, the main question is how to handle it; for it must be observed the line under operation is taxed to its utmost to handle its business, and hence the traffic must be interfered with as little as possible.

As to the masonry, the most important structures should be commenced at once, working them as fast as material can be obtained, and at the same time the minor structures, such as culverts, should be taken hold of, and such progress maintained as not to delay the grading. All the grading should be done with plows, scrapers and teams, which possibly can be done with economy, even bringing into use dump cars, on temporary tracks built for the purpose and hauled with animals, bringing into use steam shovels where the work is heavy,—in fact, do all that is within the bounds of economy without using the track in operation. As soon as this limit is reached, the permanent track should be laid and connected at both ends with the track in operation, so that work trains could use them to avoid accident or to prevent delay to the regular traffic.

The work at either end of the line next the terminals should receive the first attention, and track laid as fast as the roadbed is prepared, the

aim being to work both ways toward the centre, so that if the money fails the greatest benefit for the outlay will be had. In the first construction all side tracks used merely for passing trains and falling in the line of the second track should be utilized as such, as by so doing a gain in time is had, and every such gain is an economy, because it enables the benefits from the whole to be the sooner secured.

5. Material. As many of us know by sad experience, the vexation and anxiety of having pet schemes entirely spoiled by lack of materials, saying nothing about the cost of delay, this question should receive most careful attention. Careful estimates of what is required should be made, and then place the orders with responsible and reliable parties, and insist on prompt delivery; and to insure this it might be well to buy, or reserve from the car equipment, a sufficient number of cars to meet the requirements, and not permit them to be used in any other service. Exactly what changes to be made in bridges—whether an entire renewal with a double track structure or otherwise—should be about the first question to be settled, and contracts made for the structures, the time of delivery being clearly specified. It is better to have the superstructure wait on the substructure than vice versa.

6. Ballast: This part of the work should receive most careful attention, for in these times of heavy power an inferior ballast would be a lasting expense on the operation, and where furnace slag of good quality, or proper quality of stone could be had at a reasonable cost, they would be used, even if this cost was double that of the best gravel. As soon as the construction has fairly begun, steam shovels should be placed in the ballast pits, each provided with sufficient cars to work them to full capacity. As to the number of pits, as many as are convenient should be opened; on general principles, the more the better. For instance, for a line 100 miles would open four pits if obtainable in convenient localities, and were susceptible of easy access.

7. Organization. The work should be placed under the care of a supervising engineer, who should have a competent assistant at each end of the terminals, and a sufficient number of other assistants for the other parts of the work, depending on the length of line. And they all should give their entire attention to the work in hand.

8. Conclusion. Unless there is some special reason for doing otherwise, as, for instance, avoiding interest on the construction fund by pushing the whole work to completion in the shortest possible time, the correct plan of operation, after the location and additional lands both at terminals and along the line have been obtained, would be to have the construction of the improvements at the terminals so far along as to be assured before commencing at work at all on the line, because the nature of the work is necessarily slow, compared with the work on the line between the terminals, the time of which is measured by the force employed.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ANNUAL MEETING.

MARCH 21, 1888:—The annual meeting of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, at 4:30 P. M. President Rice in the Chair, seventy-five Members and sixteen visitors present.

The record of the last meeting was read and approved.

Messrs. Charles A. Allen, Charles W. Drake, Frederic W. Bateman, X. H. Goodnough, Charles W. Mason, William Parker and Arthur L. Plimpton were elected Members of the Society.

The following were proposed for membership: Fred. H. Barnes, of Waltham, recommended by A. F. Noyes and G. A. Kimball; Nathan S. Brock, of Boston, recommended by W. F. Learned and H. H. Carter; William H. Chapman, of Newport, R. I., recommended by G. L. Vose and A. E. Burton; Louis Cutter, of Winchester, recommended by M. M. Tidd and C. W. Folsom; William C. Hall, of South Framingham, recommended by M. T. Cook and W. F. Learned; Frank L. Locke, of Boston, recommended by J. E. Cheney and G. F. Swain; Arthur G. Robbins, of Boston, recommended by A. E. Burton and Dwight Porter; George E. Whitney, of Cambridge, recommended by M. M. Tidd and J. E. Cheney; J. L. Woodfall, of Lynn, recommended by W. E. McClintock and C. E. C. Breck, and Edward E. Young, of Hyde Park, recommended by L. B. Bidwell and S. C. Ellis.

The Treasurer presented his annual report, approved by the Auditor. The report was accepted and ordered to be printed in the Proceedings.

The annual report of the Government was read by the President. The report was accepted and ordered to be printed in the Proceedings.

The various recommendations of the Government were then considered, and on motion of Mr. F. Brooks, it was voted: That an assessment of six dollars be levied on all Resident Members of the Society.

On motion of Mr. Fuller, the Government was authorized to appoint a committee on literary exercises.

Notice was given in writing of the following proposed amendment to By-law 11, as recommended by the Government:—The Secretary shall be, *ex officio*, a representative of the Society on the Board of Managers of the Association of Engineering Societies; additional representatives shall be elected as provided for the Government of the Society.

Mr. Swan presented and read the report of the Committee on Weights and Measures. On motion of Mr. Stearns, the report was accepted and ordered to be printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

On motion of Mr. F. Brooks, the Committee on Weights and Measures was authorized to print in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES such portion of the replies to its canvassing circular as the committee thinks desirable.

Mr. Manley, for the Committee on Preservation of Timber, presented a verbal report.

Mr. FitzGerald presented and read the annual report of the Committee on National Public Works. The report was accepted and ordered to be printed in the Proceedings.

Mr. Brackett presented the annual report of the Committee on Excursions, which was accepted.

Mr. Woods presented and read the annual report of the Committee on Library. The report was accepted and ordered to be printed in the Proceedings.

Mr. Stearns presented for the Committee to nominate officers for the ensuing year the following list of candidates :

For President—E. C. Clarke, D. FitzGerald, C. Herschel.

For Vice-President—H. A. Carson, C. W. Folsom, M. M. Tidd.

For Secretary—D. Porter, S. E. Tinkham, F. O. Whitney.

For Treasurer—J. R. Freeman, E. W. Howe, H. Manley.

For Librarian—J. A. Gould, Jr., J. A. Tilden, H. D. Woods.

The report of the Committee was accepted, and after appointing committees to receive, sort and count the ballots, the Society proceeded to the election of officers for the ensuing year, with the following result:

President, Desmond FitzGerald. (Second ballot).

Vice-President, Frederic P. Stearns. (Second ballot).

Secretary, S. Everett Tinkham.

Treasurer, Henry Manley.

Librarian, Henry D. Woods.

Mr. Thomas Aspinwall was appointed Auditor by vote.

On motion of Mr. F. Brooks, it was voted: That the several special Committees of last year be continued, and that the membership of the same be left with the Government with full power.

[*Adjourned*].

S. E. TINKHAM, Secretary.

ANNUAL DINNER.

Upon the adjournment of the annual meeting the Members of the Society and their guests, to the number of 104, sat down to the sixth annual dinner. President L. Frederick Rice presided, and had on either hand as the principal guests of the evening: J. J. R. Croes, Vice-President American Society of Civil Engineers; Joseph M. Wilson, President Engineers' Club of Philadelphia; M. L. Holman, President Engineers' Club of St. Louis; Hon. George G. Crocker, Chairman Board of Railroad Commissioners; E. P. Fisk, Chairman Committee on Drainage of Mass. Legislature; J. N. Lauder, President New England Railroad Club; Henry M. Howe, Vice-President American Institute of Mining Engineers; Arthur V. Abbot, Chief Engineer National Super-Heated Water Company of New York; and E. R. Jones, late Superintendent Boston Water-Works.

After ample justice had been done to the excellent bill of fare, President Rice introduced the following speakers:

Mr. J. J. R. Croes, who expressed his pleasure at being present, and extended to the Society the congratulations of the officers and members of the American Society of Civil Engineers. He alluded briefly to the history of that Society, its mission, and defined somewhat the qualifications for membership. He also referred to the high positions to which several members of the Boston Society had been called in other cities.

Mr. Desmond FitzGerald, who was introduced as the recipient this year of the Norman Medal of the American Society and President-elect, returned thanks for the honor which the Society had done him and then entertained the Members with descriptions of some of the novel experiences of his early professional life in the West. Mr. E. P. Fiske, of the Drainage Committee of the State Legislature,

spoke of the large amount of sewerage work that would have to be done in this State in the near future and of the movement before the present Legislature looking towards the establishment of a Commission on Drainage and Water Supply, and hoped the Members would give the Committee the benefit of their advice. Mr. G. G. Crocker thanked the Members of the Society for the assistance and advice which they had given the Railroad Commissioners a year ago at the time of the Bussey Bridge investigation. In concluding he paid a most eloquent tribute to the nobility of the profession of the civil engineer and the work they had accomplished.

Mr. J. M. Wilson spoke in behalf of the Engineers' Club of Philadelphia. He referred to the important place which the local engineering societies filled and to their great benefit to the profession. He advocated a closer union of the local societies with the American Society, in some form wherein they should still preserve their local organization. Mr. M. L. Holman, of the St. Louis Club, followed, expressing the belief that a union might be effected which would be mutually advantageous. He also spoke of the method which had been tried with success in the St. Louis Club, of laying out a programme of the papers and discussions to be given at the meetings of the Club at the beginning of the year.

Mr. H. M. Howe spoke of the broader ground taken by the mining engineers in their requirements for membership, their restrictions being very slight, and though failure had been predicted in consequence, still thus far it seemed to him the plan had proved very successful.

Mr. J. N. Lauder, after expressing his pleasure at being present, alluded to the harmony with which the Boston Society and the Railroad Club occupied the same rooms. He also bore his testimony to the advantages to be derived from the free discussion of problems and experiences which were met in active professional work.

Mr. F. P. Stearns and Mr. Clemens Herschel closed the speaking of the evening.
S. E. TINKHAM, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS FOR THE YEAR 1887-88.

The time has arrived when, in accordance with the Constitution of our Society, it becomes the duty of the Government to make its Annual Report.

It is pleasant to remark the continued prosperity of our organization, as is evinced by a few statistics to which your attention is invited.

At our Annual Meeting one year ago, the Society comprised 6 Honorary, 1 Corresponding and 177 Active Members, a total of 184.

During the year now ended the Society has lost by death, 1 Honorary Member ; by resignation, 5 Active Members ; dropped from the list, 1 Corresponding and 2 Active Members, a total of 9 ; and has received an accession of 18 new Members, making a net gain of 9 and leaving a present membership comprised of 5 Honorary and 188 Active Members, a total of 193.

There are 17 applications for membership now before the Society for action, 7 of which are to be balloted upon at this meeting.

Your Treasurer's report shows a net gain of \$225.45 to the funds of the Society. The report of your Librarian shows an addition to our library list of 205 numbers. So much for the mere material gain.

In furtherance of the higher and more direct objects of our Association, the diffusion of scientific information, the interchange of professional experience, and the promotion of acquaintance among members of our profession, there have been held 10 regular and 1 special meetings. At these the attendance has aggregated 539,—453 Members and 86 Visitors,—the smallest attendance at any meeting having been 27 and the largest 84, or an average attendance of 49,—41 Members and 8 Visitors.

Well worthy of mention, as tending to promote the social feature of our organization, are the informal lunches in the restaurant of the Boston & Albany R. R. station, where from twenty to thirty of our Members have met on the evenings of our regular meetings, and by a temperate and judicious assimilation of the carnal repast there spread before them (at 25 per cent. off from the regular rates) have prepared themselves for the intellectual feast above, of which some idea may be gathered from the following menu :—

March, 1887.—Memoirs of deceased Members Sickels and Lunt, by Mr. Doane.

April.—Talk on Bridge Details, by Professor Swain.

April, special.—Discussion of Bussey Bridge.

May.—Paper on Woods; their structure, decay, etc., with stereopticon illustrations, by Mr. Dudley.

June.—Paper on the Land Slide at Dover, by Mr. Philbrick.

September.—Paper on the Filling of South Boston Flats by Mr. Hodgdon.

October.—Reading of a paper by our late deceased associate, Prof. Wm. Ripley Nichols, upon the "Action of Water on Service Pipes;" also, a Talk on Bridge Details by Prof. Swain, with more talk by others.

November.—Paper on the "Plant of the Boston Heating Company," by Mr. Abbot.

December.—Paper on the Racine Water Works and the solution of problems met with in their construction by Mr. Ellis; followed by remarks upon Dry Dock Construction by Mr. Tidd.

January, 1888.—Paper on Cement Testing, by Mr. Sondericker.

February.—Paper upon the Sewerage of Medfield, by Mr. Brooks, followed by an account of the Sewage Treatment at Mystic Lake by Mr. Learned.

During the year the pleasant and profitable feature of excursions to points of professional interest has been continued.

Visits have been made to Dudley's dynograph car, the testing-room of the Boston Water-Meter Testing Commission, the Chestnut and Fisher Hills Reservoirs of the Boston Water-Works, the Arnold Arboretum, the Bussey Bridge, the Bellevue Hill stand-pipe at West Roxbury, and Brother Manley's strawberry patch, the White Mountains, and the Warren steamer "Michigan."

The proceedings of the Society, as during the several preceding years, have been published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Early in the year a committee appointed by the Society appeared before the Railroad Committee of the State Legislature to advocate a State inspection of bridges. The Railroad Commission was authorized and directed to cause such inspection to be made.

Some correspondence has been had with reference to the suggested establishment of a Corps of Civil Engineers in the United States Government Service, for the purpose of designing and constructing such public works as are non-military in their character. The Society, as a body, has refrained from committing itself to any course of action.

This Society has adopted a similar non-committal course with relation to the project for establishing closer relations between the various local engineering associations of this country or continent.

In concluding this report, the Government of the Society makes the following

RECOMMENDATIONS.

That an assessment of \$6 be levied upon all Active Members of the Society at this date, for the purpose of defraying the expenses of the coming year, the above indicated amount being subject to such modifications in the case of non-resident and other members, as are specially provided in our By-Laws.

That the Government be authorized to appoint an Advisory Committee on Literary Exercises. It is the duty of the Government to see that due entertainment is provided at our meetings, but it is felt that its labors would be greatly facilitated

if it were empowered to call to its aid some of the intellect which is not embraced within its own body.

That By-Law 11 be amended so as to read :

"The Secretary shall be, *ex officio*, a representative of the Society on the Board of Managers of the Association of Engineering Societies ; additional representatives shall be elected as provided for the Government of the Society."

Respectfully submitted,

L. FREDERICK RICE, President.

F. P. STEARNS, Vice-President.

S. E. TINKHAM, Secretary.

HENRY MANLEY, Treasurer.

H. D. WOODS, Librarian.

BOSTON, March 21, 1888.

ABSTRACT OF TREASURER'S REPORT FOR THE FINANCIAL YEAR, 1887-88.

Current Fund—Income.

Cash at beginning of year.....	\$61.86
Non resident dues 1887-8, 7 members @ \$4.....	28.00
Non resident dues 1888-9, 19 members @ \$4.....	76.00
Assessment levied Mar. 16, 1887, 142 members @ \$6.....	852.00
Interest on deposit.....	16.34
From new Members for JOURNAL	23.25
Gift.....	4.00
Transferred from Permanent Fund.....	200.00
	<hr/>
	\$1,261.45

Current Funds—Expenditures.

Association of Engineering Societies.....	\$601.05
Library, binding and periodicals.....	63.32
Printing, postage and stationery.....	219.02
Secretary's salary (2 years).....	200.00
Annual dinner	44.50
Janitor, etc.....	22.25
Cash on deposit	111.31
	<hr/>
	\$1,261.45

Permanent Fund.

Cash at beginning of year.....	\$896.56
Nin teen entrance fees.....	190.00
Interest.....	86.00
	<hr/>
	\$1,172.56
Less transfer to current funds.....	200.00
	<hr/>
Cash on deposit March 16, 1888.....	\$972.56

Schedule of the Funds of the Society March 16, 1888.

One Republican Valley Railroad 6 per cent. non-exempt bond No. 2, par value.....	\$600.00
One Atchison, Topeka & Santa Fe "Plain 5" bond, No. 99, par value.....	1,000.00
Permanent fund cash.....	972.56
Current fund cash.....	111.31
	<hr/>
	1,083.87
	<hr/>
	\$2,683.87
Schedule presented at last annual meeting.....	2,458.42
	<hr/>
Net gain.....	\$225.45

HENRY MANLEY,
Treasurer.

REPORT OF THE COMMITTEE ON NATIONAL PUBLIC WORKS.

[Submitted at the Annual Meeting of the Boston Society of Civil Engineers, 1888.]

BOSTON, March 20, 1888.

To the Boston Society of Civil Engineers :

The Committee on National Public Works respectfully report the following brief summary of the present state of the effort to establish a new Bureau of Harbor and Water-Ways.

Within the past year considerable progress has been made by the Executive Board of the Council of Engineering Societies towards formulating their views, comparing and digesting reports from various sources, and finally presenting a bill in detail to the Congress of the United States for their adoption.

A great deal of valuable and instructive matter was compiled by the Committee who had particularly in charge the subject of examining the present systems in use in other countries. The result of these labors is appended to this report, and its perusal is recommended to any one who desires to go into a more comprehensive investigation of the several steps which have led to the draughting of Senate Bill No. 1,448. This bill is entitled "A bill for the establishment of a bureau to be known as a Bureau of Harbor and Water-Ways."

As this bill has already been made public and its provisions pretty well discussed in the papers, your Committee deem it unnecessary at this time to enter into an elaborate description of its provisions. A copy, however, is appended to this report. It may be well to state that the following re-arrangement of the corps is intended to be effected :

There will be 1 chief engineer, 4 associate chief engineers, 9 department engineers, 50 division engineers, 100 1st assistant engineers, 200 2d assistant engineers, 250 cadets.

We have suggested changing the title of 1st Assistant Engineer to that of Resident Engineer, as being, in our opinion, more in accord with the nature and extent of his duties.

Your Committee have been careful to take no action which would in any way involve the Society; in fact, the position which they have occupied has been that of watching the progress of the work which others have been doing to see what form the result would take rather than that of advocates of any particular scheme. Your Committee, however, are unanimously of the opinion that the time has arrived when the hands of those who have faithfully worked for the interests of a better administration of the public works of the country should be strengthened, and as this can be done by the individual work of the Members of the Society, as well as by the Society itself, your Committee have prepared the following petition to Congress, which they urge Members to sign. They have also prepared a second paper in the form of a personal subscription paper, for the purpose of helping to defray some of the legitimate expenses of committees sent to Washington to urge upon members of Congress the importance of adopting the bill.

Your Committee are aware that this bill may not meet the views of all engineers who have given the matter attention. It would be strange if it did. It may not be sufficiently radical in its provisions; but it must be remembered that we have to take things in this world very much as we find them, and that a half loaf is better than no bread. Of one thing we may rest assured, viz., that if the Civil Engineers of this country get a fair show in the administration of the public works of the government, the result will be a more efficient and fully as capable a service.

DESMOND FITZGERALD,	} Committee.
WM. E. MCCLINTOCK,	
SIDNEY SMITH,	

REPORT OF THE LIBRARY COMMITTEE.

[Submitted at the Annual Meeting of the Boston Society of Civil Engineers, 1888.]

BOSTON, March 21, 1888.

During the past year some 205 numbers have been added to the shelves of the library by donations, subscriptions, etc. Through the kindness of Mr. H. G. Palfrey our file of *Van Nostrand's Magazine* has been completed. Through efforts of Mr. J. A. Tilden the library has received five volumes of the *Transactions of the American Society of Mechanical Engineers*, and has been put on the regular exchange list of that society. The Society has also been able to procure the back numbers to complete its file of the *Sanitary Engineer*.

Except as regards the city of Boston and one or two other places, the collection of municipal and town reports in regard to engineering matters in the library is not as complete as it should be, considering the number of its Members engaged in this branch of the profession, many of whom, at least once a year, make official reports on such matters.

The library at present contains 510 bound volumes, 235 of which are periodicals and some 600 odd pamphlets and unbound papers. The card and alphabetical catalogues have been completed to date.

During the winter the Society's periodicals have been circulated among some two dozen Members. Owing to the more or less scattered location of these Members the plan has been but partially successful, some of the papers losing their interest by delay in getting around, while others get around quite rapidly, showing that with a little care and effort on the part of each recipient all the papers could be got around while comparatively new, and then, if desired, taken out again from the library.

A list of the periodicals, transactions and Government reports regularly received by the Society is appended.

H. D. WOODS,

Chairman of the Library Committee.

LIST OF PUBLICATIONS RECEIVED REGULARLY BY THE SOCIETY.

Periodicals.

Annales des Ponts et Chaussées, Paris, since 1876.
Electrician, London, since 1876.
Engineering, London, since 1881.
Engineering and Building Record, New York (full set), since 1877.
Engineering News, New York (full set), since 1874.
Journal of the Franklin Institute, Philadelphia, 1837 to 1852; since 1875.
Railroad and Engineering Journal, New York, since 1887.
Railroad Gazette, New York, since 1876.
Van Nostrand's Magazine, New York (full set), since 1869.

Society Transactions, Etc.

American Society of Mechanical Engineers, since 1883.
American Institute of Mining Engineers, since 1879.
American Society of Civil Engineers, since 1880.
American Water-Works Association, since 1881.
Boston Society of Arts.
Engineering Club of Philadelphia, since 1880.
Institution of Civil Engineers (Great Britain), since 1879.
Journal of Association of Engineering Societies, since 1882.
Journal of New England Water-Works Association, since 1887.
Master Car-Builders' Association, since 1882.
New England Water-Works Association, since 1882.
Société des Ingenieurs Civils (France), since 1887.
Technical Society of the Pacific Coast, since 1886.

Government Reports.

United States Chief of Engineers' Report, since 1878.
United States Coast and Geodetic Survey, since 1873.
United States Geological Survey Reports (full set), since 1880-1.
United States Geological Survey Bulletins (full set), since 1883.
United States Geological Survey Rep. on Mineral Resources (full set), since 1883.
United States Geological Survey Monographs (full set), since 1882.
United States Smithsonian Institute, since 1882.
United States Government Work, Miscellaneous Specifications.

ENGINEERS' CLUB OF ST. LOUIS.

MARCH 7, 1888:—288th meeting. The Club met at Washington University, at 8:15 P. M., President Holman in the chair; twenty-nine Members and five visitors present. The minutes of the 287th meeting were read and approved. The executive committee reported the doings of its last meeting, announcing that the names of C. T. Aubin, T. T. Johnston, T. G. Lansden, J. A. Sobolewski and J. E. Savage had been dropped from the roll for non-payment of dues.

On motion the special order of the day was then taken up, being the report of the Committee on the Waddell pamphlet on highway bridges. After a general discussion participated in by Prof. Johnson, Col. Moore, Prof. Engler, Messrs. Seddon, Bouton, Wheeler and others, the following substitute was adopted:

Resolved, That the Engineers' Club of St. Louis do not deem it advisable to endorse any individual specifications.

The Secretary read a letter from Hon. Samuel J. Randall, acknowledging receipt of the Club's resolutions on self-registering rain gauges in signal service stations.

The President formally announced the death of Frederick Shickle, one of the Charter Members of the Club. The following Committee was appointed to draft suitable resolutions: Thos. J. Whitman, Wm. Wise and T. A. Meysenburg. Mr. Engler called attention to the fact that Professor Potter, late President of the Club, had been elected to the Presidency of the American Institute of Mining Engineers, and suggested some recognition of the fact. On motion it was voted to tender Professor Potter a complimentary banquet at such time and place as would suit his and the Club's convenience; also that a committee of three be appointed to complete the necessary arrangements and have final charge of the matter. The chair appointed Professor Engler and Messrs. Wheeler and Stockett such committee.

Prof. Gale then read a paper on "Transmission of Power by Belting," giving the results of some recent experiments; also a formula for calculating the width of belt for a given power. An empirical formula which had been found correct up to 5,000 feet belt speed per minute was given. Results of tests of various kinds of belts on iron and lagged pulleys were also given. Samples of the belts tested were shown. The paper was illustrated by sketches and discussed by Messrs. Bartlett and Seddon. Owing to the lateness of the hour, it was voted to postpone Mr. Burnet's paper to the next meeting.

[*Adjourned.*]

W. H. BRYAN, Secretary.

MARCH 21, 1888:—289th Meeting.—The Club was called to order at 8:10 P. M. at Washington University by the Secretary, both the President and Vice-President being absent. There were thirty-two Members and five visitors present. Prof. Nipher was chosen Chairman *pro tem*. The minutes of the 288th meeting were read and approved. The Executive Committee reported its meeting of the same date, recommending Wm. S. Henry and John B. Myers for election to Memberships. They were balloted for and elected. The application of Russell Parker, indorsed by W. H. Bryan and S. F. Burnet, was announced and referred to the Executive Committee. Mr. S. F. Burnet then read a paper on "Cements and Mortar." He gave some practical hints on mixing and using same; also how specifications should read and tests be made. He exhibited specimens and gave results of tests. Some information on sand, water and lime was given. The damaging effects of freezing were shown. Prof. Johnson and Messrs. Bruner, Wheeler and Russell took part in the discussion.

The secretary then read a short paper by E. L. Corthell in review of one by Robert Moore on "Inter-Oceanic Ship Transfer," read before the Club March 2, 1887. The criticisms of Mr. Moore on the floating pontoon, the wheel load, comparative economy and capacity of carriage were reviewed, to show the practi-

cability of the design. Mr. Moore replied at some length, answering the points brought up, which he claimed did not change the material aspect of the problem. Professor Johnson called attention to some bars of iron which had been broken in a testing machine after having been strained beyond their elastic limit and then allowed to rest. The results were: After a rest of one day, an increase of strength of 16 per cent. was shown; seven days, 22 per cent.; sixteen days, 26 per cent.

Mr. Bruner called attention to a remarkable case of filtering water through an ordinary brick wall. Professor Nipher reported the results of some experiments on leakage of gases through brick walls.

Papers by Prof. W. B. Potter and S. Bent Russell were announced for the next meeting, April 4.

1. [Adjourned.]

WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MARCH 6, 1888 :—The 245th regular meeting was held at the hall of the Society, President Gottlieb in the chair.

The minutes of the last meeting were read and approved.

The following were proposed for membership:

Daniel Andrew With, Assistant Engineer, Town of Lake, Chicago, Ill.

Paul K. Richter, Engineer, Chicago Forge and Bolt Co., Chicago, Ill.

Ed. B. Meatyard, Real Estate, Geneva Lake, Wis.

The following were elected to membership:

Charles B. Parsons, General Contractor, Englewood, Ill.

S. Lee Heidenreich, Draughtsman, Chicago, Ill.

Robert A. Shailer, Engineer and Contractor, Chicago, Ill.

Letter ballots were canvassed for the following amendments to the By-Laws:

(Article V., Secs. 1 and 2, proposed January 3; ordered February 7.)

SECTION 1. The entrance fee shall be five dollars (\$5); said amount to accompany each application for admission, and to be returned if applicant is rejected.

SEC. 2. Members residing in Cook County shall pay dues at the rate of eight dollars and fifty cents (\$8.50) per year; all other members of every grade shall pay at the rate of seven dollars and fifty cents (\$7.50) per year.

Total number of votes cast 49; of which twelve were negative as to Section 1, and ten negative as to Section 2. The amendments were declared adopted, the extra dues to be collected when ordered by the Society.

Mr. W. S. Bates, for Committee on Annual Supper and Morehouse Memorial, reported a balance of \$16.27, which was ordered to be turned into the Treasury, the report to be placed on file and the committee discharged.

The Special Committee appointed to consider the question of "Better Provision for Rainfall Observation by the Signal Service," reported as follows:

Your Committee, to whom was referred a request from a Committee of the American Society of Civil Engineers, for the Western Society of Engineers to join in a petition to Congress in regard to Rainfall Observations by the Signal Service Bureau, submits the following resolution for adoption by the Society:

Whereas, It is deemed highly desirable by the engineering profession that better information should be collected than is now available, regarding the intensity of rainfalls in different sections of the United States, particularly with reference to the practical questions involved in the construction of works for water supply and sewerage, and

Whereas, It is entirely feasible for the Signal Service Bureau to obtain such information without increase of force, but simply by the erection of automatic, self-registering rain gauges in addition to those now employed; therefore be it

Resolved, That the Western Society of Engineers respectfully urges upon Con-

gress the desirability of inserting in the next annual appropriation bill for the Signal Service Bureau, an item sufficient to cover the expense of placing automatic rain gauges at all principal stations, as the Chief Signal Officer may direct.

Your Committee recommend that a copy be sent to the committee of the American Society having the matter in charge.

(Signed)

B. WILLIAMS,
CHAS. MAC RITCHIE, } Committee.
L. E. COOLEY,

The resolution was adopted, the recommendation approved and the Committee discharged.

The Special Committee on "Specifications for Highway Bridges," reported as follows :

The Committee to whom has been referred Mr. J. A. L. Waddell's communication in reference to his General Specifications for Highway Bridges, respectfully report as follows:

We think that improvement in the character of highway bridges, as now built, is much needed.

We do not consider that an association of bridge builders, as outlined and advocated by Mr. Waddell, is feasible, or would accomplish the results desired.

We do not consider it to be the province of this Society to recommend the adoption of the specifications of any individual.

We think that improvement in the character of highway bridges can be brought about by the following means:

The governor of each state to appoint an engineer, whose duty it will be to examine and report on existing bridges, with authority to condemn unsafe structures, and to act as expert adviser to the Legislature on all questions and measures pertaining to the construction of new work.

Cities and counties should be encouraged to employ engineers who are bridge specialists to prepare specifications and complete detail plans for bridges, and tenders from contractors should be received on the basis of these specifications and plans. In order to facilitate the adoption of this method, we think it highly desirable that engineers agree upon a scale of minimum rates for doing such work on a similar plan as in vogue among architects.

Respectfully submitted.

Signed { C. L. STROBEL,
E. C. CARTER,
A. GOTTLIEB.

The report of the committee was adopted as the sense of the Society. After considerable discussion the Committee was continued, with instructions to report at the next meeting the best practical means for carrying their suggestions into effect.

There seemed to be a unanimity of sentiment in regard to the desirability of some regulation or standard of fee practice and the establishment of a code of ethics for the profession, and that the suggestions of the Committee were a step in the right direction.

Mr. Cooley, for the Committee on National Public Works, stated that the report upon proposed legislation by the Executive Board of the Council of Engineering Societies on National Public Works, would be issued in a few days and a copy sent to each Member of the Society, and that the subject would be laid before the Society at the first opportunity.

After some general discussion the meeting adjourned.

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JANUARY 24, 1888 :—Semi-monthly meeting held, President Whitelaw in the chair. Minutes of the last meeting were read and approved.

On motion of Mr. Searles, the President was requested to appoint two committees on nominations, each committee to select and report a list of candidates for each office.

The committees were appointed as follows : H. C. Thompson, J. L. Gobeille and C. O. Arey ; John Walker, M. E. Rawson and J. D. Varney.

Mr. Searles reported the revised Constitution and By-Laws, which upon motion were recommitted to the Committee, with instructions to print and distribute among the members of the Club, with a request for suggestions as to any changes deemed necessary.

Mr. Charles Latimer read a paper entitled, "Methods of Handling Ore by Machinery," which was afterwards discussed.

[Adjourned.]

JAMES RITCHIE, Recording, Secretary pro tem.

FEBRUARY 14, 1888 :—Regular meeting held, President Whitelaw in the chair, 20 Members present. In the absence of the Secretary the stenographer, Miss Sanford, was chosen secretary pro tem.

On recommendation of the Committee on Membership, the resignation of Mr. J. C. Brewer was accepted. On motion, the resignation of Mr. W. B. Pierson was also accepted.

Mr. Eisenman, of the Committee on National Public Works, reported progress, and offered the following resolution :

Whereas, A bill has been introduced in the Congress of the United States providing that there shall be under the War Department a bureau to be known as the "Bureau of Harbors and Waterways," to be officered by a corps to be known as the Corps of United States Civil Engineers, and

Whereas, This Club is informed by its committee that the bill embodies the general features sought by the Council of Engineering Societies in which this Club is represented, and conforms to the results of its studies ; and

Whereas, These features were set forth in the action of the Convention of December, 1885, and were then adopted by this Club and other societies now represented in the Council of Engineering Societies on National Public Works ; therefore,

Be it Resolved, That the Civil Engineers' Club of Cleveland indorses the said bill, and hereby instructs its Committee on National Public Works to so notify the Council.

The report was signed by the full committee. On motion, the report and resolutions were adopted unanimously.

The Secretary having arrived, the minutes of the last meeting were read and approved.

The report of the Committee on Revision of the Constitution and By-Laws was presented by Mr. Searles, and after discussion was adopted by a ballot vote of 21 yeas to 4 nays, the necessary two-thirds vote being secured in the affirmative.

On motion, 250 copies of the revised Constitution and By-Laws were ordered printed, and the chairman of the Committee on Revision was ordered to make the necessary arrangements therefor.

On recommendation of the Committee on Membership the resignation of Mr. George W. Goetz was accepted, and on recommendation of the same committee the request of Mr. G. A. Wegner to be transferred from active to corresponding membership was granted.

Mr. H. C. Thompson reported the following list of officers nominated by his committee: For President, W. R. Warner; for Vice-President, G. A. Hyde; Sec-

retary, John L. Culley; Corresponding Secretary, E. W. Morley; Member of the Board of Managers of the Association of Engineering Societies, W. H. Searles Treasurer, S. J. Baker; Librarian, M. E. Rawson.

Mr. J. D. Varney reported the following list of officers nominated by his committee: For President, John Whitelaw; Vice-President, W. R. Warner; Secretary, James Ritchie; Corresponding Secretary, C. O. Arey; Member of Board of Managers of the Association of Engineering Societies, W. H. Searles; Treasurer, S. J. Baker; Librarian, N. B. Wood.

On motion, a committee of six was appointed, of which the President is to be a member ex-officio, to make arrangements for the annual banquet.

Mr. John L. Culley read a paper on "Landscape Engineering." No discussion.

The President announced the Committee on Banquet as follows: J. L. Gobeille, C. P. Leland, N. B. Wood, M. W. Kingsley and J. D. Varney.

[*Adjourned.*]

JAMES RITCHIE, Secretary pro tem.

FEBRUARY 28, 1888:—Semi-monthly meeting held, President Whitelaw in the chair, 12 Members present.

Minutes of the last meeting were read and approved.

Mr. James Ritchie read a paper entitled "Stadia Measurements," which was discussed by the members.

[*Adjourned.*]

JAMES RITCHIE, Secretary pro tem.

MINNEAPOLIS* SOCIETY OF CIVIL ENGINEERS.

(Formerly the Engineers' Club of Minnesota.)

OCTOBER 28, 1887:—A regular meeting was held at the City Hall, at 7:30 P. M. G. W. Sturtevant was appointed Secretary *pro tem*.

Horace E. Horton, of Rochester, Minn., was duly elected to membership in the Society.

President Sublette advocated an early adoption of the new constitution for the Society, the same to do away with the present assessment plan and substitute instead a system of semi-annual or quarterly dues.

The following names were proposed for membership, viz.: John Brawley, Peter Howe and G. W. G. Ferris, Consulting Engineers, Pittsburgh, Pa.; certified to by G. W. Sublette, Wm. W. Redfield, F. W. Capellen and G. W. Sturtevant.

A paper on Light and Gas was read by Jas. Rigby.

On motion of Mr. Redfield it was voted that the Club accept the paper, and that it be incorporated with a future paper on the same subject with the view of publishing it as an illustrated article in the JOURNAL, and that Mr. Rigby be invited to present the supplementary paper at an early date. In the course of Mr. Rigby's discussion he mentioned the causes of many of the gas explosions. The paper was discussed.

Mr. Capellen also gave a full report on the comparison of bids on superstructure of the Franklin Avenue Bridge.

[*Adjourned.*]

G. W. STURTEVANT, Secretary *pro tem*.

FEBRUARY 1, 1888:—The first meeting under the new constitution was held at the City Hall at 7:30 P. M.

Minutes of last meeting were read and approved.

The President appointed a committee to draw up resolutions of thanks to the St. Paul C. E. Club for the pleasant entertainment given by them to the Members of our Club at St. Paul, Saturday evening, January 30. The committee was as follows: E. T. Abbott, M. D. Rhame, W. W. Redfield, T. P. A. Howe, R. H. Sanford, C. O. Huntress, F. H. Capellen.

The election of officers was then held, with the following result :

President, William A. Pike ; *First Vice-President*, G. W. Sublette ; *Second Vice-President*, E. J. Abbott ; *Secretary*, Walter S. Pardee ; *Assistant Secretary and Treasurer*, C. O. Huntress ; *Librarian*, W. W. Redfield ; *Member of Board of Managers Association of Engineering Societies*, A. Rinker ; *Standing Committee on Members*, A. Rinker, M. D. Rhame, R. H. Sanford ; *On Entertainment*, Geo. W. Sturtevant, F. W. Capellen ; *House Committee*, W. W. Redfield, F. C. Deterly ; *Finance Committee*, all previous committees.

The officers submitted their annual report.

The President appointed Messrs. Huntress and Crary as Auditing Committee on the Secretary's financial report. It was voted to proceed with the election of officers.

This vote was waived, and on motion of Mr. Rinker the Secretary was instructed to devote the moneys derived from the first assessment to the payment of the debt owing the Association of Engineering Societies.

On motion, the Secretary and Assistant Secretary were exempted from all dues and fines and assessments, in view of the arduous duties attached to the offices.

Mr. Olof Hoff was elected to membership, and the resignation of Mr. Houston was accepted.

[Adjourned.]

WALTER S. PARDEE, Secretary.

FEBRUARY 15, 1888:—Regular meeting at Society Room, City Hall, 7:30 P. M. The minutes of last meeting were read and approved.

In behalf of the Committee on Resolution of Thanks to the St. Paul Club, Mr. Abbott submitted a report and copy of resolution.

The Secretary was instructed to have the resolutions engrossed at an expense of \$10, and forwarded to the Secretary of the St. Paul Club.

Mr. Abbott reported the receipt of a communication from the Executive Board Council Engineering Societies National Public Works.

Messrs. A. H. Linton and Geo. E. King were elected to membership, their names having been presented at a previous meeting under the old constitution.

The Secretary read a communication from Chas. B. Lowell, City Surveyor, Hastings, Minn., with reference to admission to the Society, and a letter of thanks was received from G. W. G. Ferris, Pittsburgh, for his recent admission to the Society. The Secretary was instructed to inform Mr. Lowell of the terms of admission and reply to the letter of Mr. Ferris.

The Society moved to have the reading of the first four sections of National Public Works Communication.

On motion of Mr. Pardee the President appointed Messrs. Abbott, Sturtevant and Huntress a standing committee on National Public Works, with instructions to correspond with the proper officers with reference to the communication received.

The name of Mr. V. L. Elbert, Superintendent Gas Works, Minneapolis, was proposed for membership, certified to by F. H. Todd and R. H. Sanford.

[Adjourned.]

WALTER S. PARDEE, Secretary.

MARCH 7, 1888 :—Regular meeting at the Society Rooms, 7:30 P. M. Minutes of last meeting were read and approved.

Messrs. Deterly and Pike submitted an amendment to Articles IX. and XI. of the Constitution, also an extension to the Constitution, to be known as Article XII.

The Secretary reported the delivery of Resolutions to the St. Paul Club.

Messrs. Pike and Huntress were appointed a committee to formulate blank forms for the use of the Society.

Mr. F. W. Handy was appointed a member of Entertainment Committee in place of Mr. Cappelen, resigned.

At the suggestion of Mr. Pike, a committee was appointed to confer with the authorities of State College of Mechanic Arts and the St. Paul C. E. Club as to a combined meeting of both Clubs at the College in the near future.

Mr. President appointed Pike, Handy, Deterly, Crary and Redfield.

Mr. Cappelen furnished the topic of discussion for the evening: further notes on the fall of the wall of St. Anthony Co. grain elevator. Mr. Cappelen having examined the wall after its fall, was called upon as an expert witness at a recent trial for damages resulting from the accident.

Although there was ample proof of a weak wall, it was found impossible to bring the facts properly before the jury, and the case against the elevator company was dismissed.

The progress of work on the city steel arch bridge was reported, and also the difficulty experienced in sinking a coffer dam in the river bed above the city.

For the next meeting Mr. Kenrick promised a paper on "Disposal of City Garbage," and Mr. Abbott on the St. Paul Cable Railway.

[Adjourned.]

WALTER S. PARDEE, Secretary.

MARCH 21, 1888 :—Regular meeting at Society Rooms, 7:30 P. M.

Meeting called to order by Vice-President Sublette.

Minutes of the last meeting were read and approved.

The Entertainment Committee submitted blank forms providing for literary work. It was voted to have printed 300 blanks and 100 postals, as per the forms submitted. The Special Committee on blank forms in general submitted specimens for inspection. The forms were adopted and ordered printed.

The paper of the evening was The Collection and Disposal of City Garbage, by R. Kenrick. Mr. Kenrick maintained that cesspools should be water tight throughout, and a system of house-to-house collection of garbage should be maintained. The objectionable privy should be replaced with dry earth closets and similar devices.

The town of Rochedale, England, was given as an example of a cleaning system, where pails emptying into carts were used. The excreta was covered with earth in an appropriate place. Easily cleaned closets replaced the old style of privies. The result of this system was satisfactory both from an economical and a sanitary point of view.

The discussion following the reading of Mr. Kenrick's paper turned upon the problem of the collection and disposal of garbage in the city of Minneapolis.

Messrs. Huntress, Sturtevant and Rhame were appointed a committee to learn what laws exist with reference to the sanitary regulations of the State and city, and to report at the next regular meeting.

[Adjourned.]

WALTER S. PARDEE, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

FEBRUARY 13, 1888 :—Regular meeting of February held one week later than usual on account of regular evening being so near the Ice Carnival week.

Meeting called to order by the President at 8 o'clock in Parlor 1 of Hotel Ryan; twelve Members and one visitor present.

The minutes of the last regular and the special meeting of Jan. 11 having been read and approved, the Committee on Entertainment of the Minneapolis Engineers' Society reported a surplus on hand, after paying all bills, and upon motion the committee was instructed to divide this surplus pro rata among the Members who subscribed towards the entertainment, but who were absent on that evening.

The applications of the following persons for membership were received, and notice given that they would be balloted for at the next meeting of the Society:

S. D. Mason, Prin. Asst. Engr. N. P. Ry. Co., St. Paul.

G. N. Miller, Asst. Engr. Sewer Dept., City Engr's Office, St. Paul.

S. T. Norvell, Div. Engr. St. P., M. & M. Ry., St. Paul.

G. E. Ingersoll, St. Paul.

Letters from J. A. L. Waddell were read relative to endorsing his pamphlet on "Methods of Bridge Lettings" and "Standard Specifications for Iron Bridges," and a Committee, consisting of Messrs. Munster, Rockwell and Hunt, appointed to report on the same at the next meeting of the Society.

Upon motion a Committee upon Rooms was appointed to make arrangements with the management of Hotel Ryan for the meetings of the Society for the ensuing year and for the refreshments at the meetings.

Upon motion, it was voted to have bound any duplicate volumes of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES that the Society now possesses, and to present the same to the St. Paul Public Library.

The literary exercise of the evening was a paper read by the President, being a report to the Council of Engineering Societies upon the Methods of Conducting Public Works at present in the countries of France and Germany.

[Adjourned.]

GEO. L. WILSON, Secretary.

MARCH 5, 1888:—At 8:20 P. M. the Society met in Room 102, Hotel Ryan, President Loweth in the chair, nineteen Members and one visitor present. The minutes of the last meeting were read and approved. Upon ballot being taken the following persons, whose applications were received in February, were voted upon and elected to membership:

S. D. Mason, Principal Assistant Engineer Northern Pacific Railroad Company, St. Paul.

G. N. Miller, Assistant Engineer Sewer Department, City Engineer's Office, St. Paul.

S. T. Norvell, Div. Engr. St. P., M. & M. Ry., St. Paul.

G. E. Ingersoll, St. Paul.

The application of Mr. J. D. Estabrook, Civil Engineer of St. Paul, was received and notice given.

The report of the Committee on Waddell's pamphlet upon "Bridge Settings and Standard Specifications" was read and accepted, being as follows:

"By the Civil Engineers' Society of St Paul—

"Resolved, 1. That it considers as urgently needed a reform in the present practice of designing and letting highway bridges.

"2. That the general specifications for highway bridges as proposed in Mr. J. A. L. Waddell's pamphlet will give economical, safe and well-proportioned bridges."

The report of the Committee on Rooms, that they had made arrangements for meeting in the Hotel Ryan for the ensuing year, was received, and the announcement by the Committee that at the next meeting a lunch would be served.

The delegate of the Society to the Council of Engineering Societies brought up the subject of the bill relating to a "Board of Waterways and Harbors," now before Congress, and after some discussion the matter was laid over till the next meeting. The Committee upon a "National Board of Public Works" was instructed to send a delegate to the next meeting of the Council, to be held in Chicago. Mr. Powell was elected to take the place of Mr. Wood on this Committee.

Upon motion the name of Mr. John Grondel was placed upon the list of non-resident members during his absence; and also that of Mr. Wood during his absence. Mr. Grondel's from Jan. 1st, 1886, and that of Mr. Wood from Jan. 1st, 1888. The Secretary was instructed to have several copies of the bill for a

"National Board of Harbors and Water Ways" printed for the use of the Society. The paper of the evening was read by Mr. A. R. Starkey on the "Public Domain of the United States and its History Relative to the Rectangular System of Surveying," illustrated by a map showing all the principal meridians used in surveys in the States north of the Ohio and east of the Missouri.

[Adjourned.]

GEO. L. WILSON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

MARCH 5, 1888:—A regular meeting was held in the Club room, 19 Deardorff Building, at 7:45 P. M., T. F. Wynne in the chair.

Minutes of the last regular meeting and of the intervening meetings of the Executive Committee were read and approved.

A letter to the Committee of National Public Works from Mr. John Eisenmann, Secretary of the Council, requesting action to be taken by the Club, was read; also one from E. L. Corthell, Esq., President, thanking the Committee for their liberal subscription to defray expenses of the Council.

The report to the Council on the H. R. Bill No. 4,923 by the Kansas City Committee was read, and a report by the same committee to the Club in which it was recommended that the Club pass resolutions to indorse the said bill, and that they co-operate with the other societies in promoting it. The report was adopted, and the resolutions indorsing it, which were read at the previous regular meeting were approved, the Secretary being directed to forward them to our representatives in Congress.

A letter from Mr. L. E. Cooley with regard to certain minor revisions of the bill which would doubtless be made was read.

Resolutions to urge upon Congress the desirability of appropriating the small sum necessary to maintain recording rain gauges at Signal Service Stations were read by Mr. Kiersted, approved, and copies ordered to be sent to Washington.

The Secretary reported the following contributions to the Library: Memoir and Summary of Papers Relating to the Reorganization of National Public Works from the Council of Engineering Societies; Proceedings Engineers' Society of Western Pennsylvania; Proceedings Engineers' Society of Lehigh University.

On a canvass of ballots an amendment to Art. 4, Sec. 1, of the Constitution to include the Treasurer in the Executive Committee was adopted. H. W. Kerr was elected Member and Geo. E. Sylvester Associate Member.

The paper of the evening, "Engineers' Field Books," was read by Mr. Edward Butts, being a review of this class of literature. The author then presented the Club with a copy of "Butts' Engineers' Field Book," upon which, by motion of Mr. Talmage, he was accorded the thanks of the Club.

The following were proposed as *Members*: C. C. Gilman, by R. C. Simons; E. W. Grant, C. M. Duncan; Robert Gillham, by Wm. B. Knight, Kenneth Allen; Chas. S. Brown, by Wm. B. Knight, T. F. Wynne; James H. Grove, by Edward Butts, T. F. Wynne; E. J. Remillion, by Wm. B. Knight, T. F. Wynne; Frank Allen, by T. F. Wynne, Edward Butts; and as *Associate Members*: J. B. Hodgdon, by Wm. B. Knight, T. F. Wynne; Geo. K. Musselman, by T. F. Wynne, Edward Butts.

On motion of Mr. Talmage, it was voted that a stenographer be engaged by the Executive Committee to report the proceedings, if one can be secured for not over five dollars per meeting.

[Adjourned.]

KENNETH ALLEN, Secretary.

To the Engineers' Club of Kansas City :

GENTLEMEN: I would respectfully submit to your consideration the following resolutions :

Whereas, There is an existing want in the engineering profession for more reliable data regarding the rate or intensity of rainfall throughout the country, particularly with reference to the problems involved in sewerage and public water supply ; and

Whereas, This information can be obtained by the United States Signal Service with only the slight expenditure involved in furnishing the observing stations with rain gauges ; therefore

Resolved, That the Engineers' Club of Kansas City indorse the suggestions of the Chief Signal Officer, to locate self registering rain gauges so as to completely collect the desired information ; and

Resolved, That we urge upon both houses of Congress, through the proper representatives or committees, the desirability of inserting in the next appropriation bill an item to cover the expense of establishing these rain gauges at all the principal stations recommended by the Chief Signal Officer.

Respectfully submitted,

W. KIERSTED.

To the Engineers' Club of Kansas City, Mo.:

GENTLEMEN: Your Committee on "National Public Works" has received and examined a copy of the bill for the organization of the "Corps of the U. S. Engineers," introduced in the Senate by Senator Cullom and in the House by Mr. C. R. Breckenridge (H. R. Bill 4,923).

We believe that the proposed legislation should be indorsed and promoted by the members of this Club, both as engineers and as citizens.

Although the general and well settled policy of our country is to leave the initiation and execution of our public works to private enterprise, so far as it is possible to do so, it is universally recognized that the general regulation and improvement of our rivers and harbors must remain in the hands of the general government and be defrayed at public expense.

So long as comparatively little work was being done in this direction, only a small superintending force was required, and the charge of the works naturally drifted into the hands of the army engineers.

Now, however, this condition of affairs has been outgrown, and it has been apparent for some years that true economy and efficiency in the expenditure of the increasing sums of money which are being appropriated required the organization of a special corps, which should supplement the talent and experience already enlisted in such works, with whatever additional professional talent may be required and available from civil life.

To inaugurate such an organization is the object of the present bill. It may not be perfect, but we believe that it has been carefully considered, and that it is probably as good as can be obtained at the present time.

We therefore recommend that the Club shall pass a resolution to indorse the present bill, and to co-operate with other Engineering Societies in promoting it.

Respectfully submitted,

O. CHANUTE,	} Committee.
J. A. L. WADDELL,	
W. H. BREITHAUPT,	
CLIFT WISE,	

RESOLUTIONS ON THE CONDUCT OF NATIONAL PUBLIC WORKS.

Whereas, Believing some of the methods for the execution of the national public works of the United States, suitable as they doubtless were in the past, are now

on account of their rapid increase in magnitude and importance, in need of revision; and

Whereas, Although our military engineers are particularly educated with reference to military operations, yet many of these are notably fitted to prosecute such works; *nevertheless*, the education and training necessary are eminently those of the civil engineer, as is indicated by the large number of civil engineers in charge of such works ; and

Whereas, The uncertainty of retention in office and the impossibility of advancement beyond a certain grade both in responsibility and remuneration deter many of our most talented and able civil engineers from entering the service of the government ;

Resolved, That we, as a club, indorse the bill (H. R. 4,923) introduced before the House of Representatives by the Hon. C. R. Breckenridge, January 16, 1888, believing it to be framed so as to avoid antagonism, to be moderate, just and practicable, and that if carried out it would result in rendering this department of our government's work vastly more economical and efficient.

KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

- Axles, Effects of Temperature on the Strength of.** By Thos. Andrews. Abstract of a paper before the Institution of Civil Engineers, giving valuable experimental research on the effect of varying temperatures on the resistance to impact of railway axles. *Engr. News*, Feb. 18, 1888.
- Belting. Origin and Progress of Leather Belting.** With description of leather link belting. Paper read before the National Electric Light Association, Pittsburgh, by Charles A. Schieren. *Electrical World*, March 3, 1888; *Electrical Engineer*, March, 1888; *Age of Steel*, March 10 and 17, 1888.
- Bridge, Forth. Fife Cantilever Pier.** A two-page plate of the Fife cantilever pier of the Forth bridge, showing all of the main tubes and connections, including junction girders completed to the full height of 362 feet, the north cantilever carried out 170 feet, the first struts and braces to a height of 240 feet and 130 feet of the viaduct completed. *Engineer*, Feb. 3, 1888. A small view of the same in *Engineering*, Jan. 27, 1888, also *Engr. News*, March 10, 1888.
- , *Illinois and St. Louis.* By Theo. Cooper. Gives notes on the mode of setting and adjusting the skew backs on the insertion of the centre tube of the different spans; and the tests of the completed bridge. *Trans. Am. Soc. C.E.*, Vol. III. (1874), pp. 239-254.
- , *Long Span, Discussion of.* By Gustav Lindenthal. Gives a discussion of cantilever, general features of arch bridge, and suspended arches. *Engr. News*, March 3, 1888.
- , *A Review of.* By Prof. W. P. Trowbridge. Of the development of bridge construction, with notices of some remarkable historic bridges. *Sci. Am. Supple.*, March 17, 1887.
- , *Economical Height of Trusses for a Given Panel Width.* By John Lundie. *Jour. Assoc. Engrs. Soc.*, Vol. VII., pp. 101-103 (March, 1888).
- Cars, Canda's Cattle.** Gives description with plans, elevation and cross-section, of Canda's cattle cars. They are provided with hayracks, water-troughs and movable partitions. *R. R. Gazette*, March 2, 1888.
- Car Wheels.** Three valuable papers presented to the February meeting of the New York Railroad Club, on the guarantee for car wheels: mileage of steel-tired wheels and the safety of cast-iron wheels. *Master Mechanic*, March, 1888; *R. R. Gazette*, Feb. 24, 1888.
- Car Wheels and Axles, Their Relation to the Track.** A discussion by the members of the New England Railroad Club at its February meeting. Relates mainly to the relative merits of steel and cast-iron wheels. *Master Mechanic*, March, 1888; *R. R. Gazette*, Feb. 17, 1888; *Nat. Car & Loco. Build.*, March, 1888.

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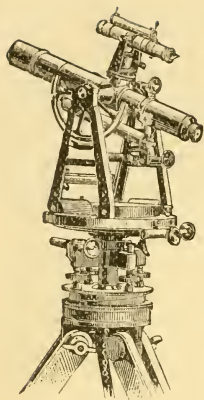
- Canal, Work on the Panama.** Gives a good statement of what has been done up to the present time. Illustrated. *Sci. Am. Suppl.*, March 10, 1888.
- , **Proposed Locks on the Panama.** Gives a description, with general view, of the proposed locks on the Panama Canal. There are to be four locks, two of 8 m. and two of 11 m. lift, on the Atlantic side, and three of 11 m. and one of 8 m. lift on the Pacific side. They are to be 18 by 18 m. *Le Genie Civil*, Feb. 18, 1888; *Engr. News*, March 10, 1888; *Engr. and Build. Rec.*, March 10, 1888.
- Cement Mortar, Economy in the Composition of.** By Prof. J. O. Baker. Discusses the use of Rosendale vs. Portland cement, of lime and cement, strength of cement mortars, quantities of ingredients required and cost of mortars. *Engr. News*, March 10, 1888.
- Cement, Influence of Sugar upon.** By H. De B. Parsons before the American Society of Mechanical Engineers. Gives details of tests of cements mixed with from $\frac{1}{4}$ to 2 per cent. of sugar and molasses. Molasses greatly retarded the setting, but at the end of two months the strength was rapidly increasing with Portland cement. One cement was too soft to take out of the molds in 48 hours. The effect appears to be per cent. of sugar gave the maximum strength with Rosendale cement. One-quarter per cent. gave maximum results. With large portions of sugar the mechanical. *Am. Eng.*, Jan. 18, 1888; *Engineer*, Jan. 27, 1888; *Engineering*, Jan. 28, 1888; *Mechanical World*, Jan. 14, 1888.
- Civil Engineers, The Education of.** By Thom. C. Clark. With discussion. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 255-266.
- Combustion, Natural and Forced Draught.** By W. G. Spence before the Northeast Coast Institution. A valuable paper giving the results of experiments with forced and natural draughts. *Engineering*, Feb. 10, et seq., 1888. An editorial on the above paper, *Engineer*, Feb. 10, 1888, and the article Feb. 17, 1888.
- Contour Lines.** By B. Feind. *Jour. Assoc. Engr. Soc.*, Vol. VII., pp. 89-92. (March, 1888).
- Dam, Masonry, Memoir of the Construction of.** By J. J. R. Croes. Gives details of the construction of a masonry dam on a branch of the Croton River, in Putnam County, N. Y., by the Croton Aqueduct Board. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 337-367.
- Dock, Alexandra, Hull.** By A. C. Hurtzig before the Institution of Civil Engineers. Gives details of the construction of the Alexandra Dock, 1881-85. The work included a dock of $46\frac{1}{2}$ acres, two miles of dock wall, two graving docks, a lock 550 \times 85 feet; embankment, 40 feet high and 6,000 feet long; and dredging an artificial channel. *Abstracted Engineering*, Feb. 10, 1888. *Abstracted Mech. World*, Feb. 18, 1888.
- Draw-Bridges.** By Clemens Herschel. Treats on the principles of construction of and the calculation of the strains in revolving draw-bridges having two spans as openings and built as continuous girders, more especially as continuous panel girders. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 395-448.
- Dynamometer, French Transmission.** Gives a description of a dynamometer constructed and used to determine the efficiency of a plant for the transmission of power by electricity. *Engineer*, Feb. 17, 1888.
- Dynamo, Eickemeyer's.** A new departure in dynamo construction, presenting apparently some marked advantages. The field coils surround the armature, and a new and ingenious method of winding the latter is described. *Electrical Engineer*, March, 1888.
- Electric Motors, Designing.** By T. Waku. Discusses the best practical method of proportioning and the proper winding of motors, and gives practical experience in the construction of special motors. *Mech. World*, Feb. 18, 1888; *T. J. and Elec. Rev.*, Feb. 24, 1888.
- Electric Welding by Means of the Arc.** An illustrated description of the method and apparatus. *Electrical World*, Feb. 25, 1888.
- Electrical Measuring Instruments, Sir Wm. Thomson's new.** A new system of standard electrical measuring instruments in which the electrical force is balanced by gravity. *Electrical World*, Feb. 25, 1888.

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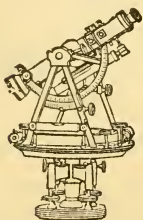
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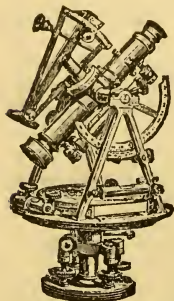
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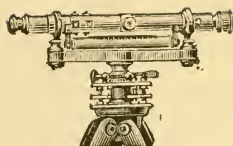
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INDEX DEPARTMENT.

- Electrical Units.** A paper by Prof. F. E. Nipher, explaining the origin and meaning of the terms volt, ohm and ampere. *Journ. Assoc. Engin. Soc.*, Vol. VII., pp 83-89 (March, 1888).
- Electricity Applied to Engineering.** By Wm. Geipel before the Institution of Mechanical Engineers. An exhaustive view of the practical application of electricity to industrial uses. Treats of the electrical transmission and distribution of power, of locomotion, lighting and metallurgy. *Engineering*, Oct. 24; *Sci. Am. Supple.*, March 10, 1888.
- Electricity, Distribution of.** By J. K. D. Mackenzie before the Society of Telegraph Engineers and Electricians. Discusses the use of secondary generators as transformers for the distribution of electricity. Gives points on the practical working of the system. *Elec. Rev.*, Feb. 17, 1888.
- Embankment, Rapid Construction.** By J. A. Smith. Describes the method adopted for filling Hall street, St. Louis, in a short space of time. *Jour. Assoc. Engin. Soc.*, Vol. VII., pp. 103-106 (March, 1888).
- Engine, Compound, at Dublin.** A short description, with a two-page plate showing plan, elevation, cross-section and valve gear [of a compound condensing engine fitted with Collman's valve gear. Cylinders are cast steel, jacketed, 14 and 20 inches in diameter, 28 inches stroke; speed, 87 revolutions; pressure, 150 lbs.; horse-power, 150. *Engineering*, Feb. 3, 1888.
- , *Rigg's High Speed.* Describes a new and ingenious type of four-cylinder revolving steam engine, capable of attaining 2,000 revolutions per minute. Illustrated. *Mech. World*, Feb. 18, 1888; *Sci. Am. Supple.*, March 10, 1888.
- , *Steam Applied to Bicycle and Tricycle.* A description of a small, light steam engine and boiler, invented by L. D. Copeland. *American Machinist*, March 3, 1888.
- , *Test of Pumping, Philadelphia Water-Works.* A report by J. L. Ogden, J. E. Codman and F. T. Hally on the duty and capacity of a 20,000,000 gallons Gaskill engine at the Spring Garden pumping station, Philadelphia. Gives the method of conducting test, with calculated and observed data. The engine gave a duty of 122,522,276 foot-pounds per 100 pounds of coal. *Eng. News*, Feb. 18, 1888.
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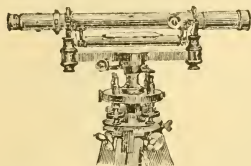
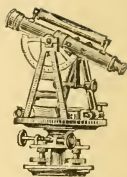


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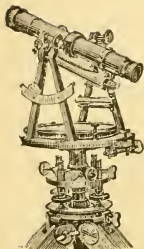
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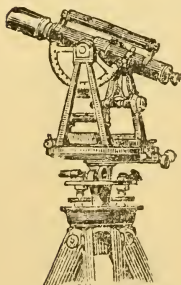
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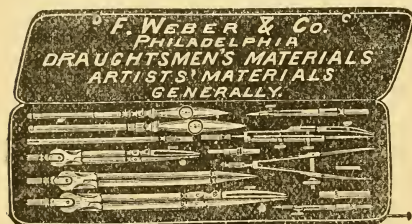
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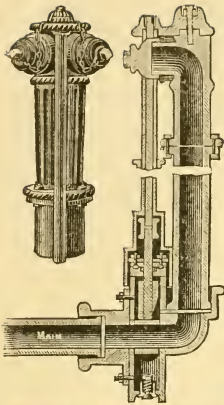
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ON A METHOD FOR MAKING THE WAVE LENGTH OF SODIUM LIGHT THE ACTUAL AND PRACTICAL STANDARD OF LENGTH.

BY PROFS. ALBERT A. MICHELSON AND EDWARD W. MORLEY, MEMBERS OF
THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read December 27, 1887.]

Abridged.

The first actual attempt to make the wave length of sodium light the standard of length was made by Pierce (1). This method involves two distinct measurements. First, of the angular displacement of the image of a slit by a diffraction grating; second, of the distance between the lines of the grating. Both of these are subject to errors due to temperature changes and instrumental errors. The results of this work have not as yet been published, but it is probable that the degree of accuracy attained is not much greater than one part in 50 or 100 thousand.

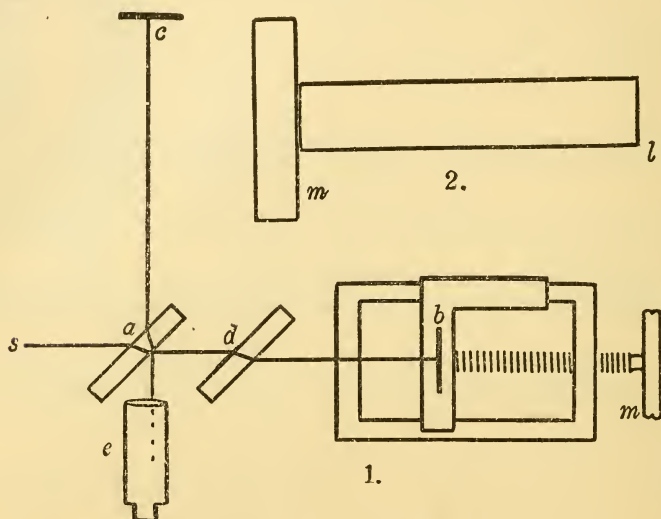
More recently Mr. Bell, of the Johns Hopkins University (2), using Rowland's gratings, has made a determination of the length of the wave of sodium light which is claimed to be accurate to one two-hundred-thousandth. If this claim is justified, it is probably very near to the limit of accuracy of which the method admits.

A short time before this another method was proposed by Macé de Lepinay (3). This consists in the calculation of the number of wave lengths between two surfaces of a cube of quartz. Besides the spectroscopic observations of "Talbot's fringes," the method involves the measurement of the index of refraction and of the density of the quartz, and it is not surprising that the degree of accuracy attained was only one in fifty thousand.

Several years ago a method suggested itself which seemed likely to furnish results much more accurate than either of the foregoing, and

some preliminary experiments made in June last have confirmed the anticipation.

The apparatus for observing the interference phenomena is the same as that used in our experiments "on the relative motion of the earth and the ether."



Light from the source at *s*, a sodium flame, falls on the plane glass *a*, and is divided, part going to the plane mirror *c*, the rest to plane mirror *b*. These two pencils are returned along *c a e* and *b a e*, and the interference of the two pencils is observed in the telescope at *e*.

The distances *a c* and *a b* being made equal by moving the mirror *b*, and the plane of *c* being made parallel with the image of *b* in *a*, and the compensating glass *d* interposed, the interference is at once visible.

If the adjustment is exact, the whole field will be dark (since one pencil experiences internal reflection at *a* and the other external).

If now *b* be moved parallel with itself a measured distance by the micrometer screw, the number of alternations of light and darkness is exactly twice the number of wave lengths in the measured distance.

Thus the determination consists absolutely of a measurement of length and the counting of a number.

The degree of accuracy attainable depends on the number of wave lengths which it is possible thus to count. Fizeau was able to observe interference when the difference of path amounted to 50,000 wave lengths.

It seemed probable that with a smaller density of sodium vapor this number might be increased, and the experiment was tried with sodium in an exhausted tube provided with aluminium electrodes, and it was found possible to increase this number to over 200,000 (4). But it is very easy to estimate tenths or even twentieths of a wave length, which means that it is possible to find the number of waves in a given fixed

distance between two planes, with an error *less than one in two millions*, and probably one in ten millions.

But the distance corresponding to 400,000 wave lengths is roughly a decimeter, and this cannot be determined or reproduced more accurately than, say $\frac{1}{500000}$, so that it would be necessary to increase this distance. This can be done by using the same instrument, together with a comparator.

The intermediate standard decimeter ab is put in place of the mirror b ; ab is a piece of cast iron, c and d are plane glass mirrors, c rests on the points of three studs, d rests on the points of three screws, c and d are made exactly parallel and the distance cd is made conveniently near to some aliquot part of the meter.

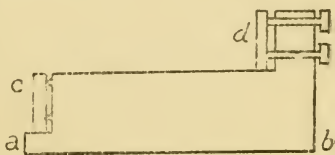


Fig. 2.

The end c is now adjusted till colored fringes appear in white light. These can be measured to within one twentieth of a wave length (probably within one-fiftieth).

The piece ab is then moved forward till the fringes appear again at d ; then the refractometer is moved in the same direction till the fringes appear again at c , and so on till the whole meter has been stepped off.

Supposing that in this operation the error in the setting of the fringes is always in the same direction, the whole error in stepping of the meter would be one in two million.

By repetition, this would of course be reduced.

A microscope attached to the carriage holding the piece ab would serve to compare, and a diamond attached to the same piece would be used to produce copies.

All measurements would be made with the apparatus surrounded by melting ice, so that no temperature corrections will be needed.

Probably there would be considerable difficulty in counting 400,000 wave lengths, but this can be avoided by first counting the number of waves and fractions in a length of one millimeter and using this to 'step-off' a centimeter. This will give the nearest *whole number* of waves, and the fractions may be observed directly. The centimeter is then used in the same way to 'step off' the decimeter, which again determines the nearest whole number, the fractions being determined directly as before.

These fractions are determined as follows:

The fringes observed in the refractometer under the conditions above mentioned can readily be shown to be concentric circles. The center has the minimum intensity when the difference in the distances ab , ac is an exact number of wave lengths. The diameters of the consecutive circles vary as the square roots of the corresponding number of waves. Therefore, if x is the fraction of a wave to be determined, and y the diameter of the first dark ring, d being the diameter of the ring corresponding to one wave length, then $x = \frac{y^2}{d^2}$.

There is a slight difficulty to be noted in consequence of there being two series of waves in sodium light. The result of the superposition of

these is that, as the difference in path increases, the interference becomes less distinct, and sometimes finally disappears, reappears and becomes most distinct again when the distance is an exact multiple of both wave lengths.

Thus there is an alternation of clear interference fringes with uniform illumination or less clear interference fringes, and if the length to be measured, the centimeter for instance, is such that the interference does not fall exactly in the middle of the series but say a tenth of the distance to one side, there will be an error of one-twentieth of a wave length, which is of the same order as the error of observation.

Among other substances tried in these preliminary experiments were thallium, lithium and hydrogen, all of which gave interference up to 50 or 100 thousand wave lengths, and could therefore all be used as checks on the determinations with sodium.

It may be noted that in the case of the red hydrogen light, the interference phenomena disappeared at about 15,000 wave lengths and again at about 45,000 wave lengths. So that the red hydrogen line must be composed of two lines about one-sixtieth as distant as the sodium lines (5).

DISCUSSION.

Mr. C. G. Force: Is the change from the black spot to the white instantaneous?

Prof. Morley: No, it is gradual

Mr. Force: Then the coincidence of the two planes is a matter of judgment.

Prof. Morley: It is; but the limits of possible error of judgment are very narrow. A motion of one plane by the hundred thousandth of an inch produces all the gradations from blackness to maximum light and blackness again. It is hardly possible to err in judgment by one tenth of this quantity, or the millionth of an inch. But if so much dependence on the judgment of the observer be deprecated, we can use micrometric measurement, and then we can trust the mean of repeated measurements even to the hundredth of a wave length, or the fifty millionth of an inch. In some observations made by use of interference phenomena (though for a very different purpose), we made the mean of our measurements 42 per cent. of a wave length, and found that the true value was 43, so that our measurements were within one per cent. of a wave length.

Prof. A. Michelson: Permit me to state that Professor Morley has given me more than my due in attributing so large a share of this work to me. Without his assistance, our present results would never have been attained.

You will observe that if we are to make our measurements, say to within one part in 10 or 20 millions, it would be an absurdity to allow the surfaces to be in error by more than the same quantity. That would mean that the surfaces must not be anywhere different from a plane more than one five hundred thousandth of an inch. So far such surfaces have not been made, no mechanician had been found who could do that work; but there is now one who will be enabled to do it, and he is Professor Morley.

Mr. Whitelaw: Do these fringes enable you to see the summit or depression of the waves of light?

Prof. Morley : The condition in which they appear when we count them may be described. Suppose our standard is adjusted so that its front mirror rigorously coincides with the image of the opaque mirror of the refractometer. This image becomes an immaterial plane of reference which we can move slowly till it coincides with the rear mirror of the standard, being throughout parallel to both. During this motion, interference fringes appear as alternate light and black circles, the one at the centre being a light or black spot of considerable size; the black or light circle outside the central spot moves inwards, taking its place, and the central spot vanishes; the other circles all move inwards at the same time. While the central black or white spot has become white or black, the immaterial reference plane has moved one quarter of a wave length; when it has again become black or white, the motion has been one half wave length. So if we count the returns of the blackness, we count the half wave lengths in the motion of our reference plane. The phenomenon is one very easy to count. I counted 4,500 wave lengths the first time I tried counting at all. If it were necessary a machine could be made to count them automatically, only needing the observer to verify the continuance of restoration of its adjustment during the process. It is as easy to count them as to count the black posts of a fence with a white background.

Mr. Warner : Can Professor Morley give us some familiar illustration of the magnitude of a wave length? He spoke the other day of a piece of split glass which would show all the colors of the rainbow.

Prof. Morley : Mr. Warner, I think, showed me a piece of glass cracked, but not broken apart. Looking at it in a proper light, a part of the light was reflected to the eye from the upper surface and a part from the lower surface of the fracture, and these two rays again united. We then got the colors of the rainbow due to interference. If you press the two parts enough to make one band of color take the place of the adjacent band of the same color, you have compressed the glass by one half wave length.

Mr. Force : You said that the temperature did not affect the measurements by this method; was that on account of your using a vacuum in counting wave lengths?

Prof. Morley : The wave length in a vacuum is the same at any temperature. It is necessary to have a good vacuum; but that is easy to obtain.

Mr. Warner : You said that the waves first issuing from the source of light have the greater amplitude. Have they any greater length?

Prof. Morley : No increase in length has been detected. The first of a series of luminous vibrations emanating from a disturbed atom have a greater amplitude, just as the first vibrations from a musical instrument of percussion have the greater amplitude.

As spherical waves pass out from their source, they have work to do on a larger scale, therefore their amplitude decreases. Imagine that an atom of sodium in a flame suffers a collision which sets it in motion. It continues to vibrate, and, like a piano string, with lessening amplitude; these vibrations are propagated outwards in all directions. As they pass outwards their amplitude decreases. Now a sodium atom may

send out, according to our experiments, as many as 200,000 vibrations before it receives a new impulse, and begins to send out a new set of waves, with perhaps the original amplitude. These 200,000 waves make a length of four inches. Suppose we could see the disturbance in a straight line of ether particles made when the set of 200,000 waves was included between the distances 30 feet, and 30 feet 4 inches from the source. The waves at the head of this line would have an amplitude one per cent. less than they had when 30 feet from the source. But the waves at the rear end of this 4 inches might have an amplitude only one-half or one third of those at the head.

We can get interference only between waves of the same set; that is, waves sent out by a sodium particle, after receiving one impulse and before receiving another. And, further, we can observe interferences only while the amplitude of the waves of this set remains sufficient. So far we have been able to observe interferences up to 200,000 wave lengths, which enables us to count wave lengths up to 4 inches.

Prof. Michelson : An article received a week ago recorded experiments made in Germany. The intensity of the light was varied from 1 to 250. There was no variation perceived in wave length. If there was any variation, it must have been less than one part in 20 or 30 millions.

Mr. Eisenmann : Is it more easy to count long waves than short?

Prof. Michelson : The shorter they are, the more easily they can be used for our purpose; the error is less.

Prof. Morley : Practically we are limited by the fact that we must take light in which we can obtain a sufficient amount of monochromatic light. Sodium light is perhaps the most convenient.

I may add that the method promises to be fruitful. It will enable us to measure expansions with an accuracy and convenience not yet attained.

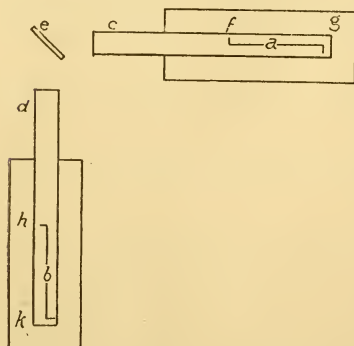


Fig. 3.

For instance, we can compare the length of a bar before and after heating. We can compare bars at the freezing and boiling points by an immaterial scale, an immaterial standard of length which cannot alter. I will show you how we can measure the expansion of a bar.

We will surround the bar *a* with a tube enclosed in a jacket in which we can have either ice or steam, so that the bar can be heated or cooled to the desired temperature. Let *b* be a similar bar in a tube surrounded by ice, and so kept of constant

length. The tubes *c* and *d* are exhausted of air. Between them at *e* we put the mirror of our refractometer. The air around it is so far from the hot or cold masses that it can be kept at a uniform temperature. Now our ray of light going from *e* to *a* and *b* is our immaterial scale, the two rays can be made exactly equal in length and are not affected by any amount of heat or cold.

First, when a and b are both at the freezing point, we make the distances ef and eh equal, and measure the difference between distances eg and ek . Second, when a is at any desired temperature and b still at the freezing point, we make distances ef and eh again equal and again measure the difference between distances eg and ek . So we measure the expansion of bar a by a scale absolutely unaffected by temperature.

Another instance: The question how much a cubic inch of water weighs is one on which scientific men of different countries are not agreed. Different determinations of the weight of a cubic decimeter of water differed by 480 milligrammes or about one-twentieth of one per cent. The reason was not inaccuracy in weighing, but the fact that the dimensions of the body weighed in water cannot be accurately determined, but by our method we can now measure the dimensions of the body to be weighed in water, and may hope to better the determination of the relation between standards of length and of weight.

Mr. Eisenmann: How are the differences of the temperatures of the bars and their supports overcome? Are they assumed to be of the same temperature.

Prof. Morley: We assume nothing. When our two cold bars have remained motionless for some time, we measure their difference in length. If we change the temperature we wait till they become motionless again, and again measure the difference. We do not even assume equilibrium. We verify the fact that the bars are motionless on their supports by examination.

Mr. Eisenmann: When I was engaged upon the old method, defining some standards, we had sweat boxes in which the temperature differed several degrees. We were not allowed to remain in the chamber more than 15 minutes.

Prof. Michelson: In the case of all comparisons made heretofore, the difference between what the thing rested upon and the thing itself had to be taken into consideration. In our experiments we do not have to consider that.

Mr. Eisenmann: After you have measured the distance from c to d in Fig. 2, and determined the number of wave lengths, is that affected by the temperature? How long must it have been submitted to a constant temperature?

Prof. Morley: We like to have our standard in ice for 24 hours. But we assume nothing. We *prove* the length c to d consists of a counted whole number of wave lengths and a fraction. The fraction can be measured in a very simple way by measuring with a micrometer the diameter of the interference fringe produced in sodium light. When this fraction remains constant, the length of the bar is constant. The observation required is as simple as the reading of a thermometer.

Mr. Eisenmann: I have observed that where the changes of temperature were sudden, a difference of 20 or 30 degrees, there was a set which was not overcome in 24 hours.

Prof. Morley: In our work our standard is first placed in an ice-box, in front of which is a refractometer. There we measure the fraction and count the whole number. When we have had it in there as long as may be required, we transfer it to our comparer, which is already in an ice-

box ; so there are no changes of temperature suffered by our standard between the time when we measure its length in wave lengths and the time when we stop off its length for comparison with, or verification of some other standards.

Mr. Eisenmann: In measuring the base of the Lake Survey, of course we worked in all seasons, so that we were subject to great changes of temperature. When we brought our work into the operating room we found that even the thermometers had a set in the glass.

Mr. Whitelaw: Would not glass be better than metal for your standards?

Prof. Morley: We tried glass first, but the artists did not succeed in making the surface plane, and we tried metal.

(1) *Nature*, xx, p. 99 (1879); *Amer. Journ. Sci.* [3], p. 51 (1879).

(2) "On the Absolute Wave-Lengths of Light," *Amer. Journ. Sci.* [3], xxxvii., p. 167 (1887); *Phil. Mag.* [5], xxiii., p. 365.

(3) *Comptes Rendus*, cii., p. 1,153 (1886); *Journ. de Phys.* [2], v., p. 411 (1886).

(4) [April, 1888.] With the light from Plücker tubes, containing vapor of mercury and thallium chloride, we have obtained interference with a difference of path of 540,000 and 340,000 wave-lengths respectively.

(5) [April, 1888.] The green thallium line has also been found to be composed of two lines about as close as in the red hydrogen line.

STATE SURVEYS.

BY CHAS. C. BROWN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read January 18, 1888.]

The amount of detail and the accuracy of public surveys which is necessary and economical depends upon the density of population and the value of land. Thus, the indefinite boundaries given in the ancient grants of land by the kings of England to the colonies and proprietors in North America, run out in part only, and by compass, and marked by blazed trees and stakes, were quite sufficient when made, while a most detailed and accurate trigonometrical and topographical survey of the British Isles, suitable for plotting upon maps with a scale of six inches to the mile, is none too good for the demands made upon it.

Every new country must pass through all the stages of progress intervening between the two thus indicated, and our own country is in a transition stage. It was but a short time, comparatively speaking, before the boundaries, as laid down in the original grants, were found to be entirely too indefinite, and many disputes arose which necessitated more definite markings and descriptions, obtained only after much wrangling and fighting, and an outlay of considerable money. Indeed, many were not even approximately settled until after the establishment of the Union, and a generous renunciation of claims to lands by different States to the General Government. I doubt if the boundaries of ten States in the Union are yet entirely settled and permanently marked beyond danger of obliteration by ordinary occurrences. The boundary between Massachusetts and New York was finally settled upon and marked, principally with "stakes and stones," one hundred years ago. But four points that could be unquestionably recognized as being upon the original line could be found in an examination of the line last summer.

The next question to that of State boundaries is that of boundaries of divisions within the States, such as county and town lines. This is in still less satisfactory condition than the first, especially in the Eastern States. In all the States settled before the adoption of the rectangular system of laying out public lands, these interior division lines follow the lines of old land grants or other arbitrary divisions, and hence are irregular in length and direction, with numerous bends and corners. In those States surveyed by the U. S. Government before settlement, the lines of division are more often straight and of fixed direction, north and south or east and west. In the Eastern States the location and marking of county and town lines is a matter of considerable doubt in almost all cases, and in a large percentage of cases is a matter of no little trouble and expense; while in the Western States it is only less doubtful because the original landmarks are more numerous and the system upon which the lands were laid out is such that within certain limits the lost corners can be approximately located from known corners. As the land becomes more valuable it becomes more necessary to have these landmarks preserved in some permanent manner, and to have the doubtful cases definitely settled. The matter is almost universally left at present to the individual towns and counties, and, as a consequence the marking of boundaries is a matter of "stakes and stones," marks which are easily obliterated when neglected, as they are almost sure to be, and when lost are often relocated incorrectly by influence of interested parties, and so become a source of endless strife and litigation. It is evident, I think, that this business should be taken in charge by the State. It is of interest to the people of the entire State, and the State is a disinterested party whose decision is most likely to be just, and will therefore be seldom or never disputed. The cost of such work as done by the New York State Survey has been given as about \$15 per mile of boundary, the average distance of monuments apart being about three and one-half miles. The territory in which this work was done happened to be quite favorable to rapid and easy location of points. Monuments were not set at all road crossings, nor was there any attempt to secure intervisibility. These should both be attended to in complete work, and would probably require two or three times as many monuments. Difficult country would increase the cost per mile perhaps as much as five times, so that the average cost of a proper marking of county and town boundaries in such a State as New York or Massachusetts would probably be from three to four times the cost mentioned per mile, or \$45 to \$60. The cost in those States surveyed by the United States Government would probably be much less than this, and it is possible the estimate of \$15 per mile would be sufficient.

The next thing to become of importance in the development of a country is a knowledge of its topographical features. We have thus far had no comprehensive system of public improvements in this country. The General Government has assumed charge of the coast line and navigable streams, both as to survey and improvement. A few States have supplemented this work within their own borders. Cities, towns and villages undertake sewerage, drainage and water supply systems with entire independence of any competent authority, often with no profe

sional advice whatever, more often with bad advice, because enough is not paid to secure good talent, and still more often with almost entire disregard of the advice given them. The systems of sewerage and drainage are thus often inefficient, often absolutely injurious to the health and property of individuals, and of other corporations, and systems of water supply are subject to pollution, are inefficient or needlessly expensive. Large sums are spent every year to repair the errors and worse than errors thus made, which would be saved almost wholly under a proper system of supervision and a proper placing of responsibility. In many places in Western States the drainage of large areas of country is impossible, because the territory is located in so many different towns that it is impossible to obtain the concert of action necessary to undertake the improvement.

Railroads have thus far been allowed the greatest liberty of action in making their plans and locations, and in construction. While in great part this liberty has been well employed, there is no question that large amounts of money have been wasted in preliminary surveys, in incorrect locations made on insufficient knowledge, in preliminary work done over lines found afterwards to be impracticable, or in swindling schemes based upon hypothetical railroads which look exceedingly well upon the map, but which are absolutely impossible upon the ground. It is estimated that \$40,000,000 have been lost in the State of New York alone, in large part by persons dependent upon small estates, a great proportion of whom are women, by investment in such schemes, when even a tolerable topographical map of the country through which the railroad is supposed to pass would show its impossibility. A similar estimate places the loss from impracticable railroad schemes in Massachusetts at \$20,000,000. These statements would apply only in less degree to Western States in proportion to the difficulties of the territory.

The principle upon which public improvements of these kinds are carried out in England is so far in advance of our own lack of any principle that I believe it is but a question of time until it is adopted in some form by the different States. In brief, no scheme for the location of a railroad or canal, for the drainage of a tract of country or the sewerage of a district, for the supply of water to a town, or for a public improvement of magnitude of any kind should be proceeded with until it has been discussed in all its relations, its relative cost and prospective income, its interference with other rights and privileges, the advisability of combining with other corporations in the same field, as well as the ordinary engineering questions. This discussion should be made by a competent and responsible body having full authority from the State to accept, reject or modify plans and to enforce its decisions.

In such case topographical maps of the territory, made by disinterested parties, would in most instances be an absolute necessity. This appears to be one of the prominent uses of the Ordnance Survey maps of England. Plans for improvements are made upon the basis of these maps, without survey, until the sanction of Parliament enables the location surveys and estimates to be made. The Ordnance Survey maps are in sufficient detail to enable the engineer to make these preliminary locations and estimates quite as accurate as the ordinary, differing by but a small per cent. from the actual location and cost. The need of topograph-

ical maps under our present American conditions is but little less than if we were working under some such plan as that suggested.

The only device that can be presented to meet all these demands and others of a similar nature is a detailed trigonometrical and topographical survey of the entire State. The trigonometrical survey furnishes the necessary accurate framework upon which to rest the boundary surveys and the topographical work. It can be carried out to any desired extent. It will be found necessary to lay out a primary system of large triangles, which should be worked out with extreme accuracy, and a network of smaller triangles, dependent upon the larger work, to locate points at distances of ten or fifteen miles from each other. It is well known that points located by triangulation are the easiest identified, if for any reason the marks for the points (made always as permanent as possible) are destroyed. Points ten or fifteen miles apart and intervisible, or from which prominent natural objects are visible are frequent enough to serve as a basis for any local surveys desired. The boundary monuments should be thoroughly connected with such triangulation, so that their location could be definitely determined should they be removed or disturbed, and so that they can be located upon the map and their relative positions determined. At the same time that the lengths of the lines in the triangulation are determined, the differences in height of the ends of the lines can be determined, thus giving a basis for a survey showing differences in height. It is now possible to determine such differences of height almost as accurately by the methods of trigonometrical leveling as by the ordinary lines of levels, and more economically if cross sections of the country are not required. The secondary system of triangulation, including therein the location of prominent objects in the landscape, such as churches, towers, prominent rocks, etc., will serve as a basis for a topographical survey which, in the most detailed surveys, will locate every prominent object and property line that will show upon maps of the largest scale desired, and will give the differences of level over the territory covered, by means of contour lines or otherwise, these lines being as close as may be deemed necessary in any particular locality. A tertiary triangulation based upon the primary and secondary work will be found advisable in the most detailed work. Evidently the cost of these surveys will depend upon the detail to which they are carried, and this detail will depend upon the value of the land, present or prospective. The primary triangulation will be necessary in any case, and a large part of the secondary triangulation, while the tertiary triangulation can be left to a future time or omitted altogether, where the land to be covered does not become sufficiently valuable to warrant its prosecution. So the topographical survey can be carried to any degree of precision from a mere sketch up. A large part of our western territories has been mapped by using the results of a preliminary reconnoissance with determinations of latitudes and longitudes at various points, some approximate triangulation in regions, and sketches of the topography, costing altogether not over \$3 to \$5 a square mile. These maps have already been found to be insufficient in some places, and a more detailed survey

is now in progress in the more important mineral districts, costing in all from \$10 to \$20 a square mile.

Topographical surveys have been made of New Jersey and Massachusetts, costing in each State about \$12 a square mile. This price included in New Jersey what triangulation was necessary to cover that part of the State not covered by the Coast Survey triangulation. Massachusetts made a triangulation of its territory about fifty years ago, and is also covered by the primary system of the U. S. Coast Survey.

This amount of money as expended under and by the U. S. Geological Survey gives a topographical survey sufficiently accurate for the scale of the maps made $\frac{1}{62500}$ (about one inch to one mile) and presents contours from 10 to 50 feet apart vertically, according to the local necessities of the case. Maps of the New Jersey and Massachusetts surveys are in process of publication at present. The cost of the surveys in these States, compared with the cost of the surveys made in the far West by the same and similar government institutions, indicates that the character of work done is no higher in the one case than in the other. It seems evident, without argument, that two such densely populated and wealthy States as Massachusetts and New Jersey will need for many years much more accurate surveys than Colorado or New Mexico. A very short time of use of the maps now publishing will show plainly the necessity for greater accuracy of survey and for maps of larger scale. The \$40,000 or \$50,000 already spent by these States is perhaps well expended in obtaining an education in the matter of the use of maps, and will indicate to other States the course for them to pursue. The same experience was passed through by England. Some portions of the territory of the British Isles have been surveyed three or four times, each time with an increase of detail of survey and of scale of map. But little, if any, was originally surveyed using as small a scale as one mile to the inch for the detail maps.

The triangulation of the two States mentioned is permanent, and can be used as the basis for any new survey. It would seem to be the most economical for States not requiring great detail of topography at this time to follow the plan of these States, and lay out a comprehensive scheme of accurate triangulation, filling in with the grade of topographical surveying considered sufficiently accurate for the locality for the present, leaving the most detailed surveys until such time in the future as their need arises. The State of New York has covered a large part of its territory, not covered by the Coast and the Lake Survey work, with an accurate primary triangulation, and considerable secondary work, upon which it is proposed to base a topographical survey. New York is following too closely in the footsteps of Massachusetts and New Jersey to profit by the lesson which they will shortly learn, and is proposing to fill in its excellent triangulation with a topographical survey upon the same scale of one mile to the inch. The amount at stake here is larger in proportion as the State is larger, and will amount to perhaps \$400,000, taking about ten years time. By the end of that time the lesson will have been brought home, and the entire inadequacy of maps upon this scale to the needs of such a State will be clearly evident, so that the money expended will be, to a large extent, thrown away.

The U. S. Coast and Geodetic Survey has an accurate system of tri-

angulation extending along the coast and through a number of States, which can be used so far as it goes as a basis for the extension of a system of triangulation, and for the framework of the topographical survey. The same use can be made of the triangulation of the U. S. Lake Survey. This will obviate the necessity in great part of the measurement of base-lines with the extreme accuracy used on those surveys (always an expensive operation), and in several States will make any system of primary triangulation unnecessary.

The United States Geological Survey seems to be willing to co-operate with any State in the prosecution of a topographical survey similar to those in New Jersey and Massachusetts, and upon similar terms, an equal division of the expenses of the topographical survey, including therein the cost of such triangulation as they use for the basis of the survey, estimated at one-third the entire cost of survey and publication of maps. Or they will leave the prosecution and expense of the triangulation to the State, and divide with it the expense of the topographical survey. This is the tenor of the offer of the director of the survey to the State of New York. For States which do not require more detailed topography than the geological survey is accustomed to give, the latter plan would be the more advisable, as the State could thus lay the permanent foundation for more detailed surveys when they become necessary, as well as the framework for the proposed survey of the present. Such a division of labor and expense reduces the expense to the individual States materially. The portion of the expense of its topographical survey borne by Massachusetts was but \$40,000 (7,800 square miles) and the portion borne by New Jersey of its survey averaged but \$6 a square mile (3,320 square miles), including some triangulation. Adding this to the estimated cost of triangulation below, \$10 to \$12, will make the present survey, including the permanent basis for better future surveys, but \$16 to \$18 a square mile for the State. There is probably not a State east of the Mississippi River for which this plan would be economical, for they are all so thickly settled, and the land is so valuable that the scale of the maps is not sufficiently large for even present uses.

The expense of the triangulation upon the U. S. Lake Survey averaged about \$15 a square mile, the triangulation extending in long lines rather than spreading out to cover a large extent of territory; in Prussia \$18, with very elaborate secondary and tertiary triangulation; and on the N. Y. State Survey has averaged about \$9.80 a square mile, with less secondary and tertiary triangulation than in Prussia, but more than on the Lake Survey, and with no base lines to measure. A comparison of the precision of the results obtained in these three surveys shows them to be of about equal merit. The case of New York State corresponds most nearly to the needs of the States of our Union at the present time, that of Prussia corresponding to the needs of some future time when more elaborate tertiary triangulation will be needed. It is probable that a satisfactory basis for any topographical survey can be obtained for \$10 to \$12 a square mile. This estimate for triangulation supposes economical expenditure of money, but at the same time first-rate work, and is probably large enough to give a system sufficiently detailed for the needs of any State for many years. The increase in cost for the more

densely populated States will come in the item of topography. There is but little territory in any of the Eastern States which can be properly represented for all purposes desired on a map with a scale of less than two inches to one mile.

The data as to the cost of such work are wanting, as none of it has been done in this country of sufficient extent to serve as any basis for an estimate, and in European countries the work has been largely done by army corps, and as such has been done under conditions so different from our own proposed work under civilian direction, that no satisfactory figures can be derived from them. It is probable that doubling the scale would at least double the cost, making the expense of topography for such maps about \$25 a square mile. At the same time the usefulness of the maps will be increased tenfold. Portions of the States will require maps on larger scales, perhaps as large as six inches to the mile in the neighborhood of cities. This increase in scale will largely increase the expense of topography, but it will be over limited areas, and a portion of the expense should properly be borne by the local authorities.

Maps upon a scale of less than two inches to one mile are of but little use for definite purposes. They are of use in giving a general idea of the surface of the country, and will thus serve as a check upon the swindling improvement schemes mentioned, and will be of use in laying out a general plan for a contemplated improvement. But the maps will not be sufficiently accurate for most of the purposes for which they should be used, and will not obviate in any great degree the necessity of extensive preliminary surveys. Maps upon the scale of two inches to the mile can be used for preliminary location, and to some extent for preliminary estimates, while maps of four or six inches to the mile can be used for most purposes for which surveys are necessary.

NOTE.—Since the above was written, an abstract from the advance proofs of the report on the Topographical Survey of New Jersey has been published, giving the total expense of the survey as \$59,892.95. Deducting \$5,143.37 not properly chargeable to the survey, it leaves an amount equal to \$6.93 a square mile. This includes about 2,000 square miles of triangulation. The statement is made that but half of this cost was borne by the State, the remainder being paid by the United States Geological Survey, under whose direction the survey was prosecuted. What little information is given in the published abstract regarding methods of work shows that the statement made above, that the amount of detail of survey is not sufficient for the uses to which such a survey should be put, is correct.

The annual report of the State Topographical Survey of Massachusetts has also appeared, announcing the practical completion of the work of preparation of a new map of the State. The work was commenced in 1884 and included a survey of 8,315 square miles within the State, and about 600 square miles along its borders. The total cost was \$115,400, of which \$40,000 was paid by the State, the remainder by the general government. Little or no triangulation is included in this amount.

The difference in cost per mile in the two states indicates that the statement that \$6.93 is the *entire* cost of the New Jersey Survey is wrong, or that there is considerable difference in the character of the work. I regret that the reports are not at hand to settle the question before the publication of this paper.

FLOORS OF STREET BRIDGES.

BY CARL GAYLER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read January 18, 1888.]

The subject of substantial floors on bridges in, or in the neighborhood of, large cities is receiving a great deal of attention in consequence of the great cost of maintenance and the inconvenience to the public, caused by repairs. I hope to be able to make some contribution to this question, owing to the experience which I have had during the last ten years in repairing and partly rebuilding the floors of the bridges in this city, principally those across the railroad tracks.

Roadway floors of street bridges can naturally be subdivided as follows :

First. Planking spiked to stringers.

Secondly. Wooden block pavement set on planks, which are either spiked to wooden stringers or secured by bolts to iron stringers.

A third class is formed by what ought properly to be called "permanent floors" which consist of a substructure of iron, *i. e.*, sheet iron riveted to beams or stringers, and of a substantial wearing surface (either wooden block pavement, asphaltum or stone pavement), with a layer of concrete between the pavement and the sheet iron to distribute the loads.

The first class—planking spiked to stringers—is still the standard bridge floor for county highway bridges all over the country; for bridges with considerable traffic, however, it is constantly losing ground, partly on account of the great cost of the necessary repairs and partly on account of the constant attention such a floor requires—a single defective plank being a source of actual danger. These two very undesirable qualities of floors of this description are being very forcibly impressed on us, year after year, by the floors of the Twelfth and Fourteenth street bridges. The roadway planking of these bridges consists of $3\frac{1}{2}$ inch white oak planks, 8 inches wide ($3\frac{1}{2}$ inches being about the maximum thickness of oak planks, which can be effectually secured by sixtypenny nails). The planks are carefully selected, and not a plank is laid down which can not be called clear lumber, and yet before the end of the second year they have to be renewed, being worn down to a thickness of about one inch. Last year we commenced to spike on top of the planking, along the outside of each street car rail, an iron flat bar 5 inches wide, and we find that the life of the planks has, by this means, been prolonged about six months. Before, a plank would not last over eighteen months. There is not much gained by the use of two layers of planks, one over the other, as it is difficult to secure the upper layer sufficiently well by spiking, and also because dampness is retained a long time between the two layers and causes them both to rot before the upper layer is worn out.

A roadway of the second class is superior to the one just now described; when new it presents all the advantages of the best kind of permanent pavements, but its real value falls very much short of its appearance during the first four or five years of its existence. The planking, and in case wooden stringers are used, the latter also will rot in about the same time, in which the block pavement, in spite of continuous repairs, is worn

out and rotten, and a company or municipality which causes such a floor to be laid, had as well make up their minds to pay for a new floor every seven or eight years.

The two classes of floors of which we have spoken do not deserve to be called more than makeshifts of a temporary character for the accommodation of traffic across bridges. They are, however, cheap, light and present some advantages in the manner in which they accommodate themselves to the changes of the bridge under varying temperatures. The cost of repairs can also be somewhat lessened by providing the bridge with iron railings and iron wheelguards. These latter form an excellent feature on any street bridge floor, and I have introduced them on all the city bridges under my control. To make them fully answer their purpose, they have to be secured directly to the ironwork of the bridge, entirely independent of the woodwork of the floor. They are then lasting; keep in line and do not interfere with the renewing of any portion of the floor.

As to the kind of timber to be used, my experience has been that, with the single exception of surface planks, which are exposed directly to wear, white pine is preferable to white oak. I have always found that a white oak stringer or wall plate will rot in three-fourths the time in which a white pine timber, under the same circumstances, will rot. When used as planking for sidewalks, white pine has the further advantage of being more easily held down by spikes and of presenting a more even surface.

The *permanent floor*, described under the third class, is the one which a sound financial policy will dictate in large cities, at least, for shorter spans. Its life, with the exception of the wearing surface, is practically unlimited and the first cost will, in the course of a number of years, be more than paid for by the saving on repairs, although this first cost is unquestionably considerable.

The following comparison of cost and weight of one square foot of different bridge floors has no claim to accuracy which could not well be obtained, as the same depends too much on varying factors: intensity of traffic, length of bridge panels, etc., but it conveys at least a tolerably correct idea of the rapid increase of cost and weight from the cheaper to the more permanent systems:

	I. Planking on wooden stringers.	II. Wooden block pavement.		III. Permanent floors.	
		a. Wooden stringers.	b. Iron stringers.	a. Wooden pavement or asphaltum.	b. Stone pavement.
Cost per sq. ft. . . .	24c.	50c.	90c.	\$1.60.	\$1.80.
Weight per sq. ft.	23 lbs.	38 lbs.	45 lbs.	140 lbs.	240 lbs.

The above figures of the cost per square foot do not include the addition to the cost of the structure itself which is caused by the increase of the dead weight, and the table of weights shows clearly that this addition forms a small item.

There are two features of these permanent floors which deserve particular attention. Both arise from the effect of temperature on the bridge structure itself, effects which do not act in the same manner on the non-metallic part of the floor, *i. e.*, the concrete and pavement. While the timber floor (Classes I. and II.) will in this respect take care of itself, inasmuch as an independent sliding movement of the timbers on the iron takes place, we have no similar self-adjustment on the permanent floors.

The two effects of temperature I am referring to are, in the first place, the expansion and contraction of the sheet-iron and stringers underneath the concrete, and secondly, those movements of the bridge under different temperatures, which are concentrated at some point of the bridge, as for instance at the roller ends of a truss bridge. The former effect breaks the bond of the concrete, the latter causes wide cracks to open across the pavement in cold weather. There is no absolute remedy for these actions of the floor in different seasons, but an increase of the thickness of the layer of concrete overcomes to a great extent the bad effect of contraction and expansion of the sheet-iron, and the damage to the pavement from open joints at the expansion joints of the bridge can either be repaired from time to time at a small cost, or special devices (cast or wrought iron covers) adopted.

PRESENT ASPECT OF THE PROBLEM OF AMERICAN INTER-OCEANIC SHIP TRANSFER.

REVIEW OF A PAPER READ BY ROBERT MOORE, MEMBER OF THE ENGINEERING CLUB OF ST. LOUIS, MARCH 2, 1887.

BY E. L. CORTHELL, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.
[Read before the St. Louis Club, March 21, 1888.]

It is intended in this review to simply correct certain mis-statements of facts which were, no doubt, made inadvertently by the writer of the paper, and from insufficient examination of the subject.

St. Louis, of all cities, is the place where Captain Eads, the projector of the Tehuantepec Ship Railway, if alive, would desire to have correct statements made about his great work. The following statements are, therefore, confined to the ship railway part of the subject.

Special attention is called to a pamphlet accompanying this review entitled, "The Atlantic & Pacific Ship Railway Across the Isthmus of Tehuantepec," in which is a detailed description of the mechanical appliances designed by Captain Eads, written by himself. This description can also be found in Johnson's new Cyclopedia. A careful reading of that description will show that Mr. Moore had not carefully considered it; for in his paper he compares the floating pontoon and the passage of the vessel from it to the land to the unstable conditions existing on a railway ferry when a train passes from it to the land. When the ship passes off from the pontoon there would be no instability from the fact that it is designed to be held in a rigid position by anchor rods or columns secured firmly in the foundations of the dock. Sufficient excess of

buoyancy is to be given to this dock by withdrawing the water from it to hold it rigidly in position when the vessel passes off from it or on to it. This can be more readily understood by reading the description alluded to.

Again, a careful reading of the description will show that Captain Eads never designed to place upon any wheel of the carriage more than 3 or 9 tons of insistent weight instead of 22 tons, and at times 60 or 80 tons, as spoken of by Mr. Moore. The carriage with 360 wheels spoken of in the paper is simply the carriage as shown in the ship railway model, and made of that size for convenience and proportioned to carry only about 3,500 tons instead of 7,000 tons. Again, the equalization of the weight of the vessel which will be accomplished by the system of hydraulic presses fully described by Captain Eads, will prevent the unequal loading of parts of the carriage or certain of the wheels.

It was hardly fair for Mr. Moore to state in one part of his paper that there would be only five turn-tables for changing the direction of vessels, and in another part to speak of these five as "numerous hydraulic turn-tables."

In reference to comparative economy by ship railway and by canal, and also as between ship railways and ordinary railways, reference is here made to the discussion of this part of the subject to be found in the pamphlet alluded to (pages 50-62 inclusive).

Much ignorance prevails in reference to weights of vessels, and Mr. Moore in his paper shows an evident lack of knowledge on this subject. He states that "Captain Eads does not propose to transport any ship greater than 7,000 tons, which would exclude all the larger vessels. It would, for example, exclude nearly all the New York and Liverpool steamers, which range from 9,000 to 13,000 tons displacement, as well as the larger Pacific Mail steamships, such as the Tokio and the City of Peking, which are 9,000 tons each." An analysis of the New York and Liverpool steamers, arranged according to their lines, is submitted, by which it will be seen that of 127 steamships, the total number in these lines, the average displacement weight when loaded is only 6,140 tons; that there are only 13 of the 127 that exceed 9,000 tons displacement, and that therefore, the New York and Liverpool steamers do not range from 9,000 to 13,000 tons displacement.

As supplementary to the above, the writer submits a table of the New York and Liverpool lines and the Peninsula and Oriental steamship line, and an analysis of the numbers and weights of sea-going steamers, made up from the Bureau Veritas of France; also, an analysis of the weights of vessels in the California wheat fleet of 1885, which includes English as well as American vessels, a traffic which the ship railway at Tehuantepec would be certain to obtain, and thus save the long voyage around Cape Horn.

There is also submitted the copy of a letter to Hon. John H. Reagan, Chairman of the Committee on Commerce, being an analysis of sea-going vessels of the United States. All of these papers bear directly upon the number and weight of vessels, and they show that a ship railway prepared to haul vessels weighing 7,000 tons will take nearly all "the larger vessels" of the world, both steam and sail, and that the vessels that

would be excluded would be a few of the Atlantic liners, which were not built for freight traffic so much as passenger traffic of a special kind, between New York and Liverpool; and another class of vessels—the large iron-clads of European nations—which neither the Nicaragua Canal nor the Panama Canal, if completed according to present plans, could accommodate, for the beam of some of them is over 70 feet, and their draught over 31 feet. It is hoped that this review of Mr. Moore's letter will be published in the proceedings of the St. Louis Club, and also in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, where the writer of this review read the paper of Mr. Moore.

COPY.

WASHINGTON, D. C., February 15, 1886.

Hon. John H. Reagan, Chairman Committee on Commerce:

DEAR SIR: The following analysis of sea-going vessels of the United States is from the report of Captain Jarvis Patten, U. S. Commissioner of Navigation on "Merchant Vessels of the United States—1885," pp. 1-59.

The total number of vessels in the table is 4,151; of these 3,853 are sailing vessels and 298 steam vessels.

Of the sail 3,759 have a displacement weight, when fully laden, of 3,000 tons or less, and constitute 95 per cent. of the whole number; 3,839 have a displacement of 4,000 tons or less, and constitute 99½ per cent. of the whole; 3853 have a displacement of 4,784 tons or less, and constitute 100 per cent. of the whole. There are none which have a displacement of over 5,000 tons. The largest ship, the Frederick Billings, has a displacement of 4,784 tons.

Of the steamers 222 have a displacement of 3,000 tons or less, and constitute 74½ per cent. of the whole number; 251 have a displacement of 4,000 tons or less and constitute 84 per cent. of the whole; 282 have a displacement of 5,000 tons or less and constitute 94½ per cent. of the whole; 291 have a displacement of 6,000 tons or less and constitute 97½ per cent. of the whole; 296 have a displacement of 7,000 tons or less and constitute 99½ per cent. of the whole. There are only two of over 7,000 tons; they have 8,886 tons, and run between San Francisco and China. Twenty-two paddle-wheel steamers plying on the Hudson River and Long Island Sound are deducted, not being intended for ocean navigation.

(Signed)

E. L. CORTHELL.

NOTE.—*March 10, 1888.*—Since the above was written the Tokio, one of the two Pacific steamers of over 7,000 tons, has been lost.

E. L. C.

ANALYSIS OF NEW YORK AND LIVERPOOL STEAMSHIP LINES.

Total number of steamships on Atlantic lines..... 127

Number having over 9,000 tons displacement ... 13

Alaska (Guion Line)	12,131	Tons.
Angoria "	9,007½	
America (National Line).....	9,664	
City of Berlin (Inman Line).....	9,607	
City of Chicago "	9,103	
City of Rome (Anchor Line).....	14,252	
Aurania (Cunard).....	12,720	
Cephalonia "	9,654	
Etruria "	13,505	
Pavonia "	9,537	
Servia "	12,936	
Oregon " [lost].....	12,907	
Umbria "	13,505	

Six Largest on Atlantic Lines.

City of Rome (Anchor Line).....	14,252
Aurania (Cunard).....	12,720
Etruria "	13,505
Servia "	12,936
Oregon " [lost].....	12,907
Umbria "	13,505

WHITE STAR LINE.

Minimum displacement	6,487 $\frac{1}{4}$ tons.
Maximum	8,764 "
Average	7,468 " — 12 ships.

GUION LINE.

Minimum displacement	4,467 $\frac{3}{4}$ tons.
Maximum	12,131 "
Average	6,670 " — 9 steamers.

ROYAL MAIL.

Minimum displacement	1,776 $\frac{1}{4}$ tons.
Maximum	6,658 $\frac{3}{4}$ "
Average	4,526 $\frac{1}{2}$ " — 25 steamers.

MONARCH LINE.

Minimum displacement	2,393 $\frac{1}{2}$ tons.
Maximum	7,637 "
Average	5,683 $\frac{1}{2}$ " — 7 steamers.

NATIONAL LINE.

Minimum displacement	3,207 tons.
Maximum	9,664 "
Average	6,590 $\frac{4}{10}$ " — 13 steamers.

STATE LINE.

Minimum displacement	4,047 tons.
Maximum	6,875 "
Average	4,715 " — 6 steamers.

INMAN LINE.

Minimum displacement	5,391 tons.
Maximum	9,607 "
Average	8,006 " — 6 steamers.

ANCHOR LINE.

Minimum displacement	1,818 tons.
Maximum	14,252 "
Average	4,798.7 " — 27 steamers.

CUNARD LINE.

Minimum displacement	2,824 tons.
Maximum	13,505 "
Average	6,801.2 " — 28 steamers.

PENINSULAR & ORIENTAL (SUEZ CANAL ROUTE).

Minimum displacement	3,211 tons.
Maximum	8,773 "
Average	5,994.9 " — 52 steamers.

AVERAGE OF ALL NEW YORK AND LIVERPOOL LINES.

Average displacement	6,140 tons.
Steamships	127

STEAMERS IN BUREAU VERITAS REPERTOIRE GENERAL, 1885-86.

Comprising all sea-going steamers afloat (every nationality) of 100 gross register tons and over.

	Number.	Percentage of total.
Under 3,000 tons disp., or 1,710 G. R. T.	6,334	75.9
Under 4,000 tons disp., or 2,280 G. R. T., and over 3,000 tons disp.	1,087	12.9
Under 5,000 tons disp., or 2,850 G. R. T., and over 4,000 tons disp.	400	4.75
Under 6,000 tons disp., or 3,420 G. R. T., and over 5,000 tons disp.	251	3
Over 6,000 tons disp., or 3,420 G. R. T.	292	3.45

Total number of sea-going steamers afloat over 100 tons gross register, including all nationalities, in December, 1885

8,414 100.00

A small number of paddle steamers included in the above, but probably less than 1 per cent.

Of the steamers under 3,000 tons disp., or 1,710 G. R.,

476	are under	200	tons gross register.
1,227	" between	200 and 400	" " "
1,004	" "	400 " 600	" " "
861	" "	600 " 800	" " "
703	" "	800 " 1,000	" " "
826	" "	1,000 " 1,250	" " "
731	" "	1,250 " 1,500	" " "
556	" "	1,500 " 1,710	" " "

6,384 steamers under 1,710 tons gross register.

The California wheat fleet of 1885 consisted of 236 vessels, of which, according to Captain Patten's rule, there were

	Vessels.
Under 4,000 tons weight.....	153
4,000 to 5,000 tons weight.....	63
5,000 to 6,000 tons weight.....	16
Over 6,000 tons weight.....	4
Vessels.....	236

The extraordinary displacement load of these vessels is due to the fact that they are loaded down below the ordinary load water line, and sometimes carry from 25 to 30 per cent. more than safe rules would allow.

REPLY BY MR. ROBERT MOORE.

[Read March 21, 1888.]

The criticisms of the treatment of the Tehuantepec Ship Railway scheme in my discussion of "The Problem of American Inter-oceanic Ship Transfer," made by my friend Mr. Corthell, and the accompanying documents, to which he refers, do not seem to me to change in any way the essential aspects of the subject.

To make this evident, I will take up in order the various points to which he calls attention.

The first of these relates to the difficulty of getting the ship safely from the floating pontoon to the land, to which I referred as an extremely difficult and delicate operation, concerning the practicability of which, with large ships, I confessed to profound skepticism. To make clear the nature of the problem I alluded to the passage of a train off from a railway ferry, in which the mechanical conditions are precisely the same, although the scale is almost too small for comparison.

To this Mr. Corthell replies that it was the intention of Captain Eads to hold the pontoon in a rigid position by anchor rods secured firmly in the foundations of the dock, and that such an excess of buoyancy was to be given to the pontoon, by withdrawing the water, as to put the anchors in tension and prevent tipping as the ship passed on or off, a solution of the problem which is perfectly sound and satisfactory, provided the scale of the transaction be not too great. In the model of which Mr. Corthell speaks I have no doubt it could be made to work to perfection. Models are very apt to work, even where the full sized construction goes to pieces.

To properly evaluate the probabilities of success upon the working scale proposed by Capt. Eads a few figures will be helpful. To prevent motion of the pontoon as the vessel passes off from it or on to it from

the land, it is necessary to place the anchor rods under a stress equal to the full weight of the ship and cradle, which I have taken at 8,000 tons, plus the excess buoyancy of which Mr. Corthell speaks, which we cannot take at less than one eighth of the foregoing, or 9,000 tons in all. Using the ordinary unit strain of five tons per square inch for rods in tension, to bear 9,000 tons will require 1,800 square inches of metal, equivalent to 144 rods 4 inches in diameter. To prevent undue strains upon the pontoon these rods would have to be distributed along the sides, one at each end of each cross girder. The average stress upon the rods would be $61\frac{1}{2}$ tons each. But if any considerable degree of rigidity be given to the pontoons in the longitudinal direction, such as would be necessary to enable it to sustain and distribute the weight of the oncoming vessel, the strains on the rods would not be equal, but would on some of them be much greater than the average just named. The same effect would be produced by wave motions in the water, which it would be impossible wholly to prevent. To hold the rods against this pull of 9,000 tons and to provide against the unequal strains, we ought, for stability, to have to have an anchorage weight of at least double this amount, or 18,000 tons. As the effective weight of stone works submerged in water cannot be taken at over 100 pounds per cubic foot, we should require for the anchorage not less than 360,000 cubic feet of masonry, or a block 450 feet long, 80 feet wide and 10 feet deep. But nothing in any of the numerous pamphlets issued by the Ship Railway Company gives any indication of an anchorage provision such as this, or any other that is at all adequate to the necessities of the case.

There is evidence, however, that towards the end of his life, if not before, the author of this plan had come to appreciate the real magnitude of the task of holding a floating pontoon rigidly in position under these enormous and ever varying stresses, and was seeking for a plan in which this necessity was not involved. In the *Engineering and Building Record* for October 29, 1887, under the caption of "Eads' Last Work," is given a letter written to one of his assistants, February 25, 1887, ten days before his death, referring to some pencil sketches, a transcript of which is also given, in which is outlined a plan for lifting the ship by means of huge hydraulic plungers, with 44 feet stroke, set in the dock underneath the pontoon. In this plan the difficulties presented by anchor rods under tension are avoided; but in the problem of placing a system of hydraulic cylinders such as these on foundations adequate for the support of ships at a depth of 100 feet below the surface of the water, and maintaining them in working order, there emerges a new set of difficulties of even greater magnitude.

A very significant feature of these documents is a memorandum in the handwriting of Capt. Eads giving the "maximum weight of ship" as "4,000 tons gross," which suggests the idea that he had become doubtful of being able to carry ships of greater weight than this, notwithstanding his previous offer to Congress to transport ships of 7,000 tons. Still more significant is the fact that this new plan differs in every feature from those found in the publication of the Ship Railway Company. Walking and flying are not more unlike, and the bare existence of this later plan proves very clearly that by their author himself the former plans were in his last hour deemed unsatisfactory.

The next matter to which Mr. Corthell directs attention is the loading per wheel of the ship carriage, which he says it was the clearly expressed intention of Capt. Eads to keep down to ten tons per wheel, although by my computation the mean loading under a 7,000 ton ship would be 22 tons per wheel with loads on some of them two or three times this amount due to unequal distribution—figures which are only an application of simple arithmetic to the undertakings of the Railway Company, and the drawing of the carriage repeatedly published by them.

These drawings show a carriage of 30 cross girders with 12 wheels under each, or 360 wheels in all. The frontispiece of the pamphlet sent by Mr. Corthell with his paper pictures a full-sized steamer in transit on a carriage of this kind. This number 360 divided into the gross load of 8,000 tons, being 7,000 tons for the ship and 1,000 tons for the carriage, gives the quotient of 22 tons just mentioned.

To this Mr. Corthell replies that the carriage shown in these drawings was not intended for ships of over 3,500 tons, and as regards the unequal distribution of the loading to which I refer, he maintains that it would be prevented by the system of hydraulic presses described by Captain Eads in the pamphlets already alluded to.

As to the first of these points, I can only say that Mr. Corthell's statement of the limitations of the carriage shown in the publications of the Ship Railway Company must of course be accepted as final, though I must say that, in view of the offer of the company, as one of the conditions of government aid, to carry ships of 7,000 tons, and of the further fact that these drawings were sent out without any definite statement of their limit, some misapprehension was very natural and almost inevitable.

To the other claim, however, that there would be no unequal loading of the wheels, I am constrained to enter my entire disagreement. The system of hydraulic presses to which he refers as the means by which any inequality of loading will be prevented is one which adjusts the supports that transfer the weight of the ship to the carriage.

The presses are all connected together, so that the pressure per square inch is the same in each. Moreover, although the number of plungers under different transverse sections of the ship varies from seven down to one, their aggregate area is the same for each section, and the total weight placed upon each cross-girder of the carriage as it rests upon the pontoon is also the same. So far there is no disagreement.

But an equal load per cross girder is a very different thing from an equal load per wheel. For the manner in which the load is placed upon the various cross girders is altogether different. Upon some of them the load is divided among seven bearing points, while near the ends of the ship it is all concentrated at one point under the keel. And when we consider further that each girder is an elastic beam continuous over six supports we see at once that an equality in the reactions over each of the supports in all of the girders is a matter of simple impossibility. The exact value of these reactions, or in other words, the exact distribution of the loading, is a problem almost beyond solution. In an ordinary track with two rails the distribution of the weight is a matter of certainty. Each additional rail adds an element of ambiguity, until for a

track of six rails, whose relations to each other, as expressed by ordinates to a horizontal plane, are subject to constant change, the proportion of the load borne by each rail becomes wholly indeterminate. Almost the only thing we can say with certainty about them is that they are always unequal. So that even with a 3,500-ton ship on the carriage shown in the drawings the loads on a large number of the wheels will very much exceed the ten-ton limit mentioned.

In regard to the phrase "numerous hydraulic turn-tables," to which Mr. Corthell objects as "hardly fair," I can only say that, as he does object to it, I would very gladly change it, though, as I had already stated the exact number five, I cannot see how any any one could possibly be misled.

In reference to the comparative economy of transportation of ships by canal and by railway, on which in the former discussion I expressed a very decided opinion in favor of the former mode, Mr. Corthell refers to the discussion of this subject in his pamphlet on the "Atlantic and Pacific Ship Railway."

The greater part of this discussion to which he refers is a comparison of ordinary railways and ordinary canals as agencies for the transportation of freight, in which he has no difficulty in proving that, on the whole, the railway has outstripped the canal, and that a large number of canals have been abandoned as unprofitable. But, of course, no one denies that for the transportation of goods in small packages, the greater speed and certainty of the railway, and the further fact that the railway can reach every point whilst the canal can reach but a few, have given to the former such advantages as to put the canal, in most cases, out of the race.

But this after all is a matter wholly irrelevant to the subject now under discussion, which concerns not the transportation of commodities in packages easily handled, but the transportation of ships and their cargoes *en masse*, the handling of which out of water is a task of enormous difficulty, even granting it can be done at all. Nor is the railway under consideration in any sense an ordinary one. It is wholly extraordinary. Its peculiar docks and floating turn-tables, both unlike anything in existence, its enormously concentrated loads, its six rails in one track to be all kept constantly in a single plane under climatic conditions highly unfavorable—a problem in itself of extreme difficulty—its low rate of speed, in which it will have little, if any, advantage over a canal, all take it out of the category of ordinary railways and place it in a class by itself, for which the experience of other railways affords no precedent whatever. When, therefore, the author of the pamphlet in question undertakes upon the basis of ordinary railway experience to estimate the cost of transporting vessels upon the proposed ship railway, we are, I think, justified in questioning the validity of his conclusions.

The best basis for a conclusion is found in a comparison of the amount of work to be done in the two cases, such as was outlined in my former paper.

Proceeding upon this basis we find that in a canal the only work to be done is to move the ship through the water, where it is in his own element, and where the friction is a minimum. The power necessary for

this will in the case of steamers be finished by the ship itself without expense to the company. The only motive power besides will be a number of tugs with which to handle sailing vessels. If any lifting be required it will be done in locks by the action of the water in seeking its own level, with no expenditure for power except that required to move the gates. The railway upon the other hand will be obliged, first of all, to lift the ship bodily out of the water, with all the risks attending such an operation, and then to move both ship and carriage on their perilous journey over the land against a frictional resistance of an unknown value, but far in excess of any thing to be encountered in the canal. In this journey the ship must be taken safely over the five floating turn-tables, must be lifted to a summit more than 600 feet above the sea level, and then let down again in face of the ever present danger of getting loose. For every step of this whole series the railway company must furnish all the power. Its plant must embrace locomotives of the most powerful class, engines to move its turn-tables, pumps to exhaust its docks and to actuate its hydraulic machinery, with a complete outfit of repair shops and engine houses, all involving a constant expenditure of money. Measured in foot-pounds its work is vastly greater than is required in a canal, and it must be done under less favorable circumstances. Add to which the fact that the railway company must assume all the risks of accident from whatever cause, and we have abundant reason for the conclusion, reached in my former paper, that if a ship railway were in actual operation the cost of doing its work would be so great that if a canal were also to be built it is difficult to see how a single ship could afford thereafter to go by rail.

As regards the number of ships in excess of 7,000 tons, I am entirely willing to accept the figures given by Mr. Corthell. These show the average of the White Star line vessels to be 7,468 tons, and the average of the Inman line to be over 8,000 tons, whilst he gives a list of thirteen Atlantic liners which range from 9,000 to 14,000 tons. But the precise number seems to me unimportant. It is enough that ships of more than 7,000 tons are numerous, as the foregoing figures abundantly prove, and that the ship railway could not carry them. For as I have already said in my former paper: "If we are to spend \$75,000,000, or any large sum to transport vessels, we ought certainly to provide for the transportation of vessels such as these."

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 18, 1888 :—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 7.30 P. M., forty-three Members and fourteen visitors present.

President Desmond FitzGerald, on assuming the chair, spoke as follows :

I wish to take advantage of the first opportunity that has presented itself to thank the Members of the Society for the honor which they have done me in electing me their President for the present year.

I accept the duties of the office with a full realization of my own inability to fill the place of an ideal President.

The Society, however, has grown to such proportions, both in size and vigor, that it will be impossible for any one man to make or mar its fortunes.

The Government has been wisely framed in such a way that its councils are conducted by the combined judgment of all the officers. It thus becomes impracticable for any individual to get very far astray, however much he may naturally be disposed to do so.

I shall look for the support and assistance of every member to make a success of our meetings.

The first article of our Constitution declares that "the objects of this Society are the professional improvement of its Members, the encouragement of social intercourse among engineers and men of practical science, and the advancement of civil engineering."

The objects could not have been better stated.

In order to secure professional improvement it will be necessary for us to attend the meetings as far as possible and take an active interest in the papers and discussions.

It has seemed to me particularly desirable that the younger Members should take a more enthusiastic part in the proceedings, and I shall look for them to fill this part of the bill during the year.

The measures which have been already undertaken to promote social intercourse, such as our excursions and our annual dinner, seem to me to have produced already the most encouraging results.

How often our prejudices against a man disappear on a better acquaintance.

Our excursions have been particularly successful, and not a little professional information has been gathered from them. I hope that our present committee will begin soon to make some preliminary surveys for our excursion next October, perhaps into the heart of the Green Mountains, at any rate, wherever the scenery is finest, and I would suggest that some date not far from the 6th be selected, as the autumn foliage is then at its perfection.

For the advancement of the profession of the civil engineer it is necessary for us to make our organization of sufficient importance for its might to be felt in every possible direction. An entering wedge has already been driven with success in the action of some of our Committees, particularly at the State House on the Railroad Inspection Bill, and I look confidently for further developments of this course of action in the future.

In considering the best possible plan to adopt for our literary exercises, it has seemed to the Government that it would be better now at the beginning of the year, to adopt an approximate programme for all the meetings, dividing them into subjects, and as it is desirable that there should be no secrecy in these matters, I have been asked to state briefly what is contemplated.

In May we shall take up the subject of the Separate System of Sewerage ; in June, Dams ; September, House Drainage ; October, Rapid Transit ; November, Municipal Engineering ; December, Topography ; January, Duty Tests ; February, Railroads ; April, Mills ; May, Bridges. If this idea does not meet with the approval of the Members it can easily be abandoned.

Papers have already been provided for the meetings until November, but there is room for more if any Member has any subject in mind for a paper. I ask for the fullest suggestions on all these matters from the individual Members of the Society and trust that they will correspond with me freely. In closing these brief remarks I cannot help expressing the feeling that the future of the Boston Society of Civil Engineers is to be a success, but to make it such will require the earnest approval of every Member.

The record of the annual meeting was read and approved.

Messrs. Fred. H. Barnes, Nathan S. Brock, William H. Chapman, Louis Cutter, William C. Hall, Frank L. Locke, Arthur G. Robbins, George E. Whitney, J. L. Woodfall and Ed. E. Young were elected Members of the Society.

Proposals for membership were received from Edgar S. Dorr, of Charlestown, recommended by W. F. Learned and C. W. Folsom, and Edmund B. Weston, of Providence, R. I., recommended by Dexter Brackett and Desmond FitzGerald.

The President announced the death of Henry F. Walling, a Member of the Society, and on motion of Mr. Stearns, the chair was authorized to appoint a committee of three to prepare a memoir. The Committee appointed is as follows : Charles W. Folsom, Frank O. Whitney, and E. L. Brown.

The Secretary then read the following Special Committees appointed by the Government under authority of a vote of the Society passed at the last meeting :

On Weights and Measures, Charles H. Swan, Charles W. Kettell, Charles W. Folsom.

On National Public Works, William E. McClintock, Sidney Smith, L. Fred'k Rice.

On Excursions, E. W. Howe, Waterman Stone, J. A. Tilden, F. L. Fuller, E. L. Brown.

On Library, Librarian H. D. Woods, and Secretary S. E. Tinkham (*ex-officiis*), Charles H. Swan, George F. Swain, Charles S. Parsons.

Mr. Manley made a statement in relation to the permanent fund of the Society, and upon his motion the chair was authorized to appoint a committee of two, who, with the Treasurer, should invest such portion of that fund as they considered advisable. The President appointed as that Committee, Edward S. Philbrick and Thomas Doane.

The following by-law proposed at the last meeting was adopted by a vote of 26 affirmative, 0 negative : By-Law II. The Secretary shall be, *ex officio*, a representative of the Society on the Board of Managers of the Association of Engineering Societies ; additional representatives shall be elected as provided for the Government.

A paper was then read by Mr. L. Frederick Rice, Chairman of the commission appointed by the city of Boston to test meters, entitled "The Methods and Apparatus Used in the Recent Test of Water Meters at Boston."

Mr. E. B. Weston followed with a paper entitled "Notes on the Water Meter System of Providence, R. I."

A discussion ensued, in which Messrs. French, Howland, Manley, Rice and Stearns, of the Society, and Mr. J. Herbert Shedd, of Providence, took part.

[*Adjourned.*]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

APRIL 4, 1888:—290th meeting.—The Club met at Washington University at 8:15 P. M., President Holman in the chair, twenty-four Members and four visitors present. The minutes of the 289th meeting were read and approved. The Executive Committee reported its meeting of same date, recommending Russell Parker for election to membership. He was balloted for and elected.

The Special Committee on Resolutions Appropriate to the Death of Frederick Shickle reported as follows :

Resolved, That, by the death of Frederick Shickle, the Engineers' Club of St. Louis has lost a most valuable Member, one who has been with us from the beginning as a charter Member, and whose zeal and life have been devoted to engineering pursuits—a man endeared to his fellow men by his kind and genial bearing and his ever courteous and upright conduct.

Resolved, That we extend to his bereaved family our profound sympathy, and

Resolved, That a copy of these resolutions be suitably prepared and presented to the family of our lamented associate.

Committee { T. A. MEYSENBURG,
WM. WISE.

On motion the report of the committee was adopted. The President presented a communication from L. E. Cooley, President of the Council of Engineering Societies on National Public Works, on the subject of the Reorganization of National Public Works. On motion it was made the special order for the next meeting, April 18.

The Secretary then read a paper on "Railroad Location ; Field Practice in the West," by Willard Beahan. The author explained the difficulties to be overcome, and the most common methods employed. He also gave his own method, which he had used largely with very satisfactory results. The paper was discussed by Professor Johnson and Messrs. Wheeler, Seddon, Moore, Bouton and Clark. There was considerable diversity of opinion as to the best method to follow, which in every case must depend upon the character of the country to be traversed.

Professor Nipher explained to the Club a calorimeter he had prepared for the purpose of determining the heat value of fuels. It was a quick method, and gave accurate results. The apparatus was shown and a test made. After some general discussion of Western fuels, the meeting adjourned.

W. H. BRYAN, Secretary.

APRIL 18, 1888 :—291st Meeting.—The Club met at Washington University at 8.15 P. M., President Holman in the chair, twenty-seven Members and two visitors present. The minutes of the 290th Meeting were read and approved. The Executive Committee reported the doings of its meeting of same date, recommending the reinstatement on the rolls of T. G. Lansden, he having tendered the amount of his back dues. On motion it was so ordered. The Committee also reported favorably on the applications for membership of John H. Mueller and Chas. W. Stagl. They were balloted for and elected. The application for membership of Prof. Alfred E. Phillips, Lafayette, Ind., was announced and referred to the Executive Committee.

The Committee on Banquet tendered Prof. Potter submitted a report showing a balance of \$4.85, which was turned into the treasury of the Club. On motion the report was accepted and the Committee discharged.

The regular order of the day was then taken up, being the consideration of a communication from the Council of Engineering Societies on the Reorganization of National Public Works. The Secretary read the communications. Prof. Johnson moved the reappointment of a committee on national public works. Seconded.

A general discussion followed, participated in by Messrs. Johnson, Seddon, Engler, Bryan, Nipher, Burnet, Russell and Blaisdell. Mr. Seddon moved as a substitute that the matter be referred to a committee of three, to report not later than May 16th. Seconded and carried. The chair appointed as such committee F. E. Nipher, S. B. Russell and A. W. Hubbard. Mr. S. Bent Russell then read a paper on "Thickness of Water Pipe, with Some Experiments on Ram." His remarks were illustrated by a number of charts, tables and formulæ. He showed that great discrepancies existed between standard authorities on the question of thickness of pipe. In general the thickness of the smaller sizes is fixed by questions of manufacture and handling. The question of hydraulic ram was one on which very little data could be had. Mr. Russell had conducted a series of experiments himself, the results of which were shown, and an empirical formula deduced. Messrs. Seddon, Wheeler, Johnson, Holman and Blaisdell took part in the discussion.

[Adjourned.]

W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

APRIL 3, 1888:—The 247th regular meeting was held. In the absence of the President, Mr. C. L. Strobel was made Chairman *pro tem*.

The minutes of the last meeting were read and approved.

The following were elected to membership :

Daniel Andrew With, Assistant Engineer, Town of Lake, Chicago, Ill.; Paul K. Richter, Engineer, Chicago Forge and Bolt Co., Chicago, Ill.; Ed. B. Meatyard, Geneva Lake, Wisconsin.

The Secretary and Treasurer reported the finances in good condition.

The Committee on "Specifications for Highway Bridges" was not ready to submit a formal report. The subject was, however, taken up and discussed at some length on the line of the last meeting.

The Committee on "National Public Works" submitted the following report :

Your Committee reports that it has received from the Executive Board of the Council of Engineering Societies on National Public Works a publication entitled "Reorganization of National Public Works, Part I. Proposed Legislation," containing a modification of the Cullom-Breckinridge bill for the establishment of a Bureau of Harbors and Waterways, which it is proposed to urge upon Congress. A copy of this publication has been sent to each Member of the Society, accompanied by a request from your Committee for a contribution of \$2 from each Member, on Society account, and as much more on individual account as each Member can afford. This is in response to an assessment of \$1 per capita on the membership of the several societies by the Executive Board of the Council.

The publication referred to sets forth the whole question so fully that it is unnecessary for this Committee to report upon the merits of the question. It is believed that the efforts of the Executive Board should meet with the fullest co-operation and support by this Society. Your Committee, therefore, invites discussion of the proposed legislation and the adoption of the following resolutions :

MEMORIAL FROM THE WESTERN SOCIETY OF ENGINEERS TO THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED.

WHEREAS, Our National Public Works, in their legislative and administrative conduct, have, for many years, been subject to severe and just criticism, and they are without a well considered policy or a consistent purpose, and

WHEREAS, It is believed that the careful consideration of the whole question, the formulation of a definite policy and the constitution of a specific agency for

its execution, will place our public works before the people on a conceded basis of merit, will develop a definite system and secure regular appropriations, and thus rapidly develop important and necessary facilities for commerce and create new industries, therefore be it

Resolved, That the Western Society of Engineers approves the general purpose of the Cullom-Breckinridge Bill for the establishment of a Bureau of Harbors and Waterways, and believes that, in conjunction with proper changes in the Rules of Congress, it will remedy the evils now complained of.

Resolved, That the modified bill, proposed by the Executive Board of the Council of Engineering Societies, meets the approval of this Society, subject to such changes in minor details as close study may show to be desirable.

The Committee also submits the following for approval:

Resolved, That the Committee on National Public Works of this Society is authorized and instructed to promote the purpose of these resolutions.

Respectfully submitted,

L. E. COOLEY,	} Committee on National Public Works.
HEIRO B. HERR,	
CHAS. FITZSIMONS,	

CHICAGO, Ill., April 3, 1888.

The changes in the Rules of the House, which are intended to supplement the bill, were explained at length; also the general theory of the bill in regard to maintaining an efficient organization. After discussion, the report of the Committee was accepted and the memorial and resolution adopted.

[*Adjourned.*]

L. E. COOLEY, Secretary.

MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

APRIL 5, 1888.—Postponed regular meeting at Society rooms, Vice-President Sublette in the chair. Minutes of the last meeting were read and approved. The resignation of Jno. H. Barr was read and accepted. On motion he was elected an Honorary Member. On motion of Mr. Huntress it was voted to tender Mr. W. A. Pike a vote of thanks for the courtesy extended to the Society at a meeting held at the State College of Mechanic Arts on the evening of March 29. On motion of Mr. Copplelen the Society voted to tender a vote of thanks to Mr. Ferris, for a drawing of the "Coal Measures" near Pittsburgh, Pa. Mr. J. S. Haman was elected to membership.

The Committee on Sanitation, appointed at the last meeting, reported that the matter had been investigated, and Health Officer Kilrington had been invited to address the Society on "Sanitation in Minneapolis."

Dr. Kilrington here delivered his address. He gave a history of his work as Health Officer, describing the laws as they now are. The laws are all that could be desired, but the people need to be educated. The Health Department is run on business principles. There is a general supervision of contagious diseases, of food, etc. Under the State law, the Board of Health has the power to appoint its officers.

The doctor gave an interesting account of the successful handling of small-pox in the city. The State laws being especially good, there was little trouble in checking the spread of the disease. After an instructive explanation of the condition of the city water supply, he gave the results of some careful analyses of water taken from different parts of the city.

On motion of Mr. Crary, the Society tendered a vote of thanks to Dr. Kilrington for his able address.

It was voted that the Society lend its aid and hearty co-operation to the city Health Department and to Dr. Kilrington, the present health officer, in all endeavors to better the sanitary condition of the city.

[*Adjourned.*]

WALTER S. PARDEE.

ENGINEERS' CLUB OF KANSAS CITY.

APRIL 2, 1888:—A regular meeting was held. Those present were : Messrs. Knight, Waddell, Chanute, Taylor, G. W. Pearsons, Breithaupt, Hastings, Kiersted, Stern, Wade, Swain, Sylvester, Allen, and ten visitors.

Minutes of the previous meeting were read and approved.

A letter from Mr. L. E. Cooley to the Committee on National Public Works was presented by Mr. Chanute, stating that delegates from the various engineering societies would meet in Washington April 9 and 10, and requesting that the Kansas City Club be presented.

A motion by Mr. Waddell that the Club defray the necessary traveling expenses of a delegate to Washington was carried.

On motion of Mr. Chanute it was voted that the selection of a delegate be left to the Executive Committee.

Contributions to the discussion of the evening were read from Messrs. C. E. H. Campbell, of Council Bluffs, Ia.; L. G. F. Bouscaren, of Cincinnati; Geo. L. Vose, of Boston; Wm. H. Burr, of Phoenixville; Chas. L. Strobel, of Chicago, and A. J. Tullock, of Leavenworth.

It was voted to read other discussions which had been presented at an adjourned meeting to be held in the club-room at the usual time, April 16th.

On a canvass of votes the following were declared elected: As Members—Chas. C. Gilman, Robt. Gillham, Chas. S. Brown, Jas. H. Grove, E. J. Remillon, Frank Allen; and as Associate Members: J. B. Hodgdon, Geo. K. Musselman.

The following names were proposed—As Members: Daniel Bontecou, O. B. Gunn, E. I. Farnsworth, M. N. Wells, Alexander Potter and Wm. B. Upton; and as Associate Member: H. F. Hill.

[Adjourned.]

KENNETH ALLEN, Sec'y.

APRIL 16, 1888 :—An adjourned meeting was held in the Club-room, at 7:45 P. M. Those present were : Messrs. Knight, Hastings, Stern, Sylvester, F. Allen, Chanute, Waddell, Wynne, Wade, Breithaupt, K. Allen and two visitors.

Minutes of the last regular meeting and of that of the Executive Committee were read and approved.

The President reported in brief what action had been taken by the delegates at Washington respecting the Cullom Bill, stating that there would be no difficulty in its passage by the Senate, while in the House, though there was not the same unity of feeling, no great opposition was looked for.

A letter of resignation from the Club by Mr. George C. Stealy was read, and his request granted.

The discussion of Prof. Waddell's pamphlet begun in the last regular meeting was then continued as follows : A paper was read by Mr. W. H. Breithaupt : the Secretary read contributions from Prof. De Volsen Wood, Messrs. Samuel G. Artingstall, Edwin Thatcher, Prof. P. C. Ricketts and Mr. W. L. Cowles. These were discussed by Messrs. Goldmark, Wynne and Breithaupt, and replied to by Prof. Waddell.

Mr. Chanute then presented the following resolutions, which were adopted by the Club :

"First—That a committee of three be appointed by the President to prepare and submit to this Club a form of memorial to the Legislature of this State, together with a draft of a law inaugurating a proper inspection of bridges, and that for this purpose the Committee may consult with public spirited counsel.

"Second—That the Secretary be instructed to notify other engineering societies and clubs throughout this country of the action taken by the Club, and to solicit their co-operation in this movement.

"Third—That in case of the appointment of similar committees by other clubs, the committee of this Club be instructed to confer and co-operate with them in

drafting the project for the proposed law, and in drawing up general specifications and rules to guide the State Inspector."

Mr. Chanute mentioned the following means as proposed for effecting the desired reform: First, The employment of expert engineers. Second, The use of legal standards of strength, as was once recommended by the American Society of Civil Engineers. Third, The formation of a pool of responsible bridge builders, as outlined in Professor Waddeil's pamphlet. Fourth, State inspection, as now in use in Massachusetts and New York. The latter was generally considered the most feasible.

Mr. Wynne thought expense in the latter case might be avoided by inspecting the existing bridges as opportunity occurs, keeping on hand a force simply sufficient to report on new work.

On vote of the Club the above resolutions were adopted, amended by the substitution of "Executive Committee" for the word "Club" in the first clause.

The Chair appointed as Members of the Committee proposed Messrs. Chanute, Waddell and Breithaupt.

[*Adjourned.*]

KENNETH ALLEN, Secretary.

COUNCIL OF ENGINEERING SOCIETIES ON NATIONAL PUBLIC WORKS.

OFFICIAL MINUTES OF EXECUTIVE BOARD.

Pursuant to the call of the President, the Executive Board met at Wormley's Hotel, Washington, D. C., at 8 P. M., Nov. 9, 1887; present, Cooley, Corthell, Eisenmann and Barbot. After an informal discussion the following was ordered spread on the minutes:

This call of the Executive Board is on the suggestion of Hon. C. R. Breckinridge, for the purpose of meeting the President of the United States, who has evinced an interest in the purposes of the Council. The committee on preparation of matter, etc., reports orally that it has compiled and submits in typograph several letters, viz., A Historical Sketch of the Council, a Memorial to the President, a Brief for a Proposed Bill and papers on the Public Works of the United States, France and Prussia; also that it has prepared and bound a collection of several printed papers in regard to our public works policy, and the Proceedings of the Council.

Nov. 10, 1887.

Second Session.

The Executive Board met at the house of Hon. C. R. Breckinridge, at 10 A. M. Present: Cooley, Corthell, Eisenmann, Barbot and Kurth. Continued in session until 7 P. M. Discussed the entire question of proposed legislation. To carry out the purposes of proposed legislation in full it was concluded that certain changes in the Rules of the House would be desirable. It was also concluded to leave with Mr. Breckinridge a copy of all matter prepared to enable him to make a draft of a bill.

Nov. 11, 1887.

Third Session.

The Executive Board met at Wormley's at 2:30 P. M., and repaired to the White House at 3 P. M., per appointment with the President. The general purpose of the Council was fully presented, and the President expressed himself in hearty accord with any change in the present policy which would place the river and harbor works of the government upon a thoroughly broad and national basis. He realized fully the evils incident to present methods, and anticipated that men familiar with the requirements of such works would propose wise and comprehensive legislation.

At 4:30 P. M. an adjourned meeting was held at Wormley's.

On the suggestion of Mr. Cooley, Mr. Hiero B. Herr was added to Committee

on preparation of matter and the Committee directed to finally collate and publish such matter as would be useful in advancing the objects of the Council.

Mr. Cooley was directed to confer with Mr. Breckinridge on the morrow in regard to some provisions of the proposed bill, and to have the draft sent to Members of the Executive Board and others who had been making a study of the subject, if possible, before its introduction in Congress.

The Committee was also directed to send copies of the papers thus far compiled to the several Committees of the Council, and to submit any recommendations in regard to the bill at a future meeting of the Executive Board.

Mr. C. H. Talmage, C. E., who had been present at the sessions of the Board, was elected an Associate Member.

Mr. Breckinridge was thanked for his courtesy and assistance.

At 9:30 P. M. the Board adjourned subject to the call of its President.

(Signed), JOHN EISENMANN, Secretary.

CHICAGO, Ill., March 17, 1888.

Pursuant to the call of the President, the Executive Board met at 171 LaSalle street, at 10 A. M. Present, Cooley, Corthell, Loweth and Eisenmann.

Minutes of Board meeting at Washington, Nov. 9, 10 and 11, 1887, were read, and on motion of Mr. Corthell were approved and ordered spread on the record.

Mr. Cooley presented and read the report of Committee on Compilation and Publication of Matter, as follows :

"On April 1, 1886, a committee was constituted 'to collect and digest all information on the Public Works Systems, and formulate conclusions which are to be submitted to the Societies represented for discussion, and as a result, to present a final report and bill for presentation to Congress.'

"At a meeting of the Executive Board, June 20, 1887, reports were received from three sub-committees, Haupt, Barbot and Kurth; and recently from a fourth sub-committee, Davis. The Committee gave this and other matter collected earnest consideration, and prepared a digest for a law. The matter was compiled and laid before the Executive Board in Washington on Nov. 9, 10 and 11, 1887.

"At this meeting the Committee was directed to place the matter compiled before the several society committees of the Council at an early day and also to print the same for distribution.

"The matter was also placed in the hands of the Hon. C. R. Breckinridge to aid him in drafting a bill which was submitted to the Committee and others for suggestions, and finally to the members of the Executive Board and several Members of the Council. As modified up to Jan. 16, the bill was introduced in the Senate by Hon. Shelby M. Cullom (S. 1,448) and in the house by Hon. C. R. Breckinridge (H. R. 4,923). Since the bill was printed it has been quite widely circulated and a large number of communications in relation thereto have been received. As a result of farther study, a modified bill is herewith submitted for the consideration of the Board.

"The matter collected, in typograph, was sent to the several society committees of the Council. The Committee has re-arranged this and, with additions, submits herewith the advanced sheets of Part I., covering that bearing most immediately on the proposed legislation.

"Part II., a collection of more general matter, in partially arranged, as also Part III., and these it is proposed to publish as soon as finances may justify.

"In Part I., such minor alterations in the bill as seem obviously desirable have been appended as amendments.

"The Committee submit this as a progress report and awaits the farther instructions of the Board.

"Signed,

L. E. COOLEY.
E. L. CORHELL.
JOHN EISENMANN.
HIERO B. HERR."

Approved March 17, 1887.

Matter contained in Part I. was presented by advance sheets, and instructions for its distribution adopted as follows :

1. An edition of 5,000 to be printed at once and plates stereotyped.
2. A copy to be sent to each Member of each Society in the Council, and each committee to be supplied with such further copies as it may require ; five copies to be sent to each Associate Member ; one copy to each Subscriber to the Fund, and to prominent members of the profession ; the Secretary to supply calls.
3. A copy to be sent to the President of the United States, to the Secretary of each department, to each member of Congress, to each member of the United States Engineer Corps, to other prominent officers of the Government, and to such public men as may take an interest.
4. Copies to be sent to leading public libraries, to selected members of technical societies not in the Council, to scientific schools, to the technical and daily press, commercial bodies, marine organizations, officers of waterway conventions, and generally to such organizations and individuals as may promote the purposes of the Council.

Part II. The Committee is authorized to select from the matter now on hand, or which may be received, from periodicals, the press and correspondence, any matter calculated to advance the general cause, and to publish as soon as prepared.

Part III. The Committee is authorized to compile and to publish after further orders of the Board.

The Cullom-Breckinridge bill, with amendments, reported by the committee, was revised by the Executive Board, and as an amended bill suggested by the Executive Board, was ordered printed and appended to Part 1 as a Supplemental Report.

The Secretary and Treasurer presented detailed report of receipts and expenditures to date with outstanding liabilities. Received and filed. Aggregate statement ordered spread on the minutes as follows :

RECEIPTS.

Total from organization to date—Cash from Western Society of Engineers, Engineers' Club of Kansas City, Engineers' Club of Philadelphia, Engineers' Club of St. Louis, Civil Engineers' Club of Cleveland, Civil Engineers' Society of St. Paul, Cornell Association of Engineers, Iowa Society, Ohio Society, Technischer Verein, New York ; Technischer Verein, Chicago, and Michigan Engineering Society.....	\$631.09
Cash from individuals.....	181.00
	<hr/> \$812.09

EXPENDITURES.

Total from organization to date—For printing, postage, stationery, expressage, copying, etc., etc.....	\$547.34
	<hr/> 547.34
Cash in treasury.....	\$264.75
Outstanding liabilities.....	\$386.88
(Signed) JOHN EISENMANN, Treasurer.	

It was ordered that the several societies in the Council be requested to contribute \$1 for each Member, and that they be given credit on this account for all money previously received ; also, that a request for funds be sent to other societies ; also, that each Associate Member be requested to raise \$25 ; that a request for contributions be sent to all individuals who may take an interest in the question. The Publication Committee was instructed to draft and issue suitable circulars covering the above.

The Board elected several Associate Members, subject to their acceptance, in districts not represented by societies, and the Secretary was instructed to correspond with them by circular with a view to obtaining their co-operation.

At 1:25 P. M. a recess was taken. At 2:15 P. M. Board again called to order by President Cooley.

It was ordered, that each Society be requested to call the attention of local boards of trade, chambers of commerce, and other commercial and maritime bodies to the matter contained in Part 1 and to urge that they take favorable action thereon. Each Society should pass suitable resolutions in regard to proposed legislation, and through its Committee call the attention of Congressmen to the importance of the measure. Each Committee should actively interest itself in raising the Society quota of money and obtain individual subscriptions from all who can be persuaded to take an interest. The Publication Committee was instructed to draft and issue a suitable circular covering the above and urge immediate action thereon.

The Publication Committee submitted a draft of an Address to the Technical Professions to accompany the issue of Part 1 and for miscellaneous circulation. Adopted, and Committee instructed to print and issue the same.

It was ordered, That the Executive Board meet in Washington at some date yet to be fixed to present the matter to the Committees of Congress, and that they invite others to assist in the presentation.

At 4:10 P. M. adjourned subject to the call of the President.

(Signed) JOHN EISENMANN, Secretary and Treasurer.

MEMORANDUM.

Pursuant to a call by the President, the Executive Board met in Washington on April 9th, for the purpose of laying the work of the Council before the committees of Congress. Present : Cooley, Corthell, Kurth and Walter P. Rice as proxy for Mr. Eisenmann. There were also present to assist the Board Wm. B. Knight, President Engineering Society of Kansas City, Mo. ; Prof. L. M. Haupt, of the Philadelphia Society ; Hiero B. Herr, of the Western Society, Chicago, Ill., and Gen. Thos. L. Rosser. Letters were received from Loweth, Davis and Barbot, of the Executive Board, and also from D. J. Whittemore and Clemens Herschel, who were unable to be present. No formal meeting was held.

On Monday, April 9, a hearing was had before the Senate Committee on Commerce, from 10:30 A. M. to 12:30 P. M. The subject was gone into as fully as the time permitted, a large portion of the time being taken up in interrogations by Senators. The desirability of something different from present practice seemed to be fully recognized by the Committee, and the reception which the presentation received was far more favorable than the delegation had anticipated. In fact, it seemed that the several years' campaign which the Council had entered upon was likely to be greatly reduced. The testimony was taken by stenographer for printing.

On Tuesday, April 10, the delegation appeared before the House Committee on Expenditures in the War Department, from 10:30 to 12:00 A. M., and went over the same ground, with results equally auspicious.

Many members of the two houses were seen during the three days, and an active interest found to exist. The desirability of some change seems to be fully and intelligently recognized among those who have given the matter attention. River and harbor legislation of any kind is an impelling motive among many, if not the majority, from the pressure of constituencies and sections, but this does not blind them to the grave evils existing and for which a remedy should be provided. If this measure of practical reform is adequately supported by the profession and the intelligence of the country, it will not linger long in the halls of Congress.

One Senator remarked : "The folly of the present system has been recognized in the Senate for years. The people press for these improvements, and we have to go on. If this is the measure of practical reform which I think it is, you need not be surprised to see it go through speedily ; that is, in the course of two or three

sessions, or as soon as Congress can study so grave a matter. It may be like other matters which had been given up as hopeless. A practical solution is proposed, and finds sentiment ripe for its consideration."

In *The Forum* for May, Senator Cullom has written an article on "Appropriations for Public Works" which deserves the thoughtful consideration of every engineer and citizen. While presenting an excellent perspective of the views of the Council, he adds thereto his large experience in matters pertaining to the commerce of the country, and especially as to the legislative character of river and harbor bills. He emphasizes one fact which seems to have been overlooked by critics of this movement, viz.: That Congress, or its committees, virtually assume the functions which in all other countries are delegated to a public works organization, and that when Congress creates an organization specifically adapted to its work and to perform these functions, it will have corrected most of the evils of the present situation.

The Council is to be congratulated on the present favorable status of the movement and on the results which will surely, in good time, attend its labors. The situation is full of encouragement, and as the scope and intent of the measure and the actual inadequacy of present methods for any wise end are appreciated, opposition will fail. The merits of the question may be trusted, without reply to aspersions of motive. Let every engineer assist in a good cause, and if he finds on full information and study, that the measure is imperfect, his patriotic aid is due to this cause and not to the opposition.

(Signed)

L. E. COOLEY, President.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

- Accidents, Railroad, in February.** A classified list of railroad accidents for the month of February will be found in *R. R. Gazette*, March 30, 1888.
- Boilers, Gas Fired.** Gives a description of Frederick Siemens' improvement in generating steam with gaseous fuels. *Sci. Am. Supple*, March 31, 1888.
- , *Locomotive, Belpaire Type.* Gives detailed drawings of a 56-inch straight top boiler designed for the new Mogul engines on the Chicago, Burlington & Quincy Railroad. *Master Mechanic*, March, 1888.
- Brakes, Buffer.** A brief article explaining, with formulæ, the nature and action of buffer brakes. *Master Mechanic*, April, 1888.
- Brake, Manomatik.** Gives a description of the Manomatik lever momentum brake, which is operated by power transmitted from the drawheads through buffersprings. Illustrated. *R. R. Gazette*, March 23, 1888.
- Bridge, Brooklyn, Enlarging the Capacity of the.** Gives the report of the Board of Experts on the plans for enlarging the capacity of the Brooklyn bridge; also the report submitted to the Board by Mr. A. M. Wellington. *Engr. News*, March 17, 1888.
- , *Cantilever, Sakkar.* By Wm. Parsey. Gives a description of staging and temporary erection of the Sukkar cantilever bridge at the bridge works. The bridge has a span of 820 feet, with a centre span of 200 feet. A two-page plate gives details of staging, etc. *Engineering*, March 2, 1888.
- , *Pile and Trestle.* By A. F. Robinson. Discusses the use of pile and trestle bridges, and gives design of the standard trestle of the Chicago, Burlington & Northern Railroad Company. *Engr. News*, April 7, 1888.
- , *Pins and Eye Bars, Proportion of.* By C. F. Stowell. Discusses the present state of pin calculation and gives formula for computing the stress in the side of the head of eye-bars. *Engr. News*, March 31, 1888.
- Cars, Six-Wheel Trucks for Freight.** By J. M. Barr, before the March meeting of the Western Railroad Club. Discusses the use of the collarless axle and advocates the use of six-wheel trucks for freight cars of 60,000 lbs. capacity. *Master Mechanic*, April, 1888. *R. R. Gazette*, March 23, 1888; *Nat. Car and Loco. Builder*, April, 1888.
- Car, Standard 50,000-lb Gondola.** Gives detailed drawing, with abstract from specification for the standard 25-ton gondola car of the Newport News & Mississippi Valley Co. *R. R. Gazette*, April 6, 1888.
- Car Heating.** *Test of the McElroy System.* Gives details of test of McElroy system of continuous heating made on the Hudson River Railroad. *R. R. Gazette*, April 6, 1888.
- Car Wheels and Tires.** By C. F. Allen, before the March meeting of the New England Railroad Club. Discusses the question of safety in the use of wheels and tires. Followed by discussion. *Master Mechanic*, April, 1888; *Nat. Car and Loco. Builder*, April, 1888; *R. R. Gazette*, March 23, 1888.

BOOKS FOR ENGINEERS.

NEWMAN, JOHN. Notes on Concrete and Works in Concrete. Especially written to assist those engaged upon works. The result of many years practical experience. 38 pages, 12mo, cloth, \$1.50.

DYE, F. Hot Water Supply : A practical treatise upon the fitting of hot water apparatus for domestic and general purposes. 81 pages, 12mo, cloth, \$1.00.

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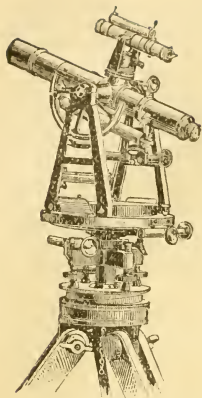
- Cement.** *Statement of the Industry.* A statement showing the extent of the industry in the United States. *Enginr. and Build. Rec.*, March 17, 1888.
- Cement Mortars,** *for use in Public Works.* An abstract of a report by the Executive Board of the City of Rochester, N. Y., prepared by Emil Kurchling. *Engin. and Build. Rec.*, March 24 and 31, 1888.
- Chart.** *The Pilot Chart of the North Atlantic Ocean.* Lecture before the Franklin Institute, by Everett Hayden, of the United States Hydrographic Office. Presents a copy of the pilot chart for March, 1888, and interesting description of it. *Journal of the Franklin Institute*, April and May, 1888.
- Dredge, Rock, Suez Canal.** An illustrated description of the sub-aqueous rock dredger "Dèrocheuse" built for the Suez Canal. Its dimensions are $180 \times 40 \times 12$ ft. It has ten chisel bars, 42 ft. long, weighing four tons each, and dredging machinery to remove the broken rock. Its capacity is about 40 tons per hour. *Engineer*, March 9, 1888.
- Driven Wells as a Source of Water Supply for Cities.** By Albert F. Noyes. A valuable contribution to the subject, giving many important facts and generalizations. *Jour. New Eng. W. Works Assoc.*, June, 1887.
- Economy in Structures.** *The Proper Method of Comparison.* A paper by Prof. G. W. F. Swain before the *New Eng. Water-Works Assoc.* Gives formulæ which take account of the several variables in the problem. In their *Journal* for March, 1888.
- Engine, Economy of the Non-Condensing.** By P. W. Williams before the Institution of Civil Engineers. Gives details of a series of economy trials made on a triple expansion engine used as a simple, compound or triple engine. *R. R. Gazette*, April 6, 1888; *Mechanical World*, March 24, 1888.
- , *Marine, Development of.* A series of illustrated articles with the object of describing and illustrating the marine engines in the existing ships of the British Navy, and to trace the development of the engine from the type fitted in the oldest of them to that at present being fitted in the most modern. *Engineer*, March 23, *et seq.*, 1888.
- Electricity.** *The Volt, the Ohm and the Ampère.* A mathematical exposition of the method employed in fixing the values of these units. Read before the Engineers' Club of St. Louis, by Prof. F. E. Nipher, of Washington University. *Journal of the Association of Engineering Societies*, March, 1888.
- Forests.** *Their Influence on Rainfall.* A paper by Prof. Geo. F. Swain, giving an able and rational discussion of the subject, and including a synopsis of the known facts relating thereto. *Jour. New Eng. W. Works Assoc.*, Vol. I., No. 3.
- Friction, Recent Researches in.** By John Hoodman, before the Students of the Institution of Civil Engineers. Gives a comparison of the results obtained by various authorities and examines the phenomena from a theoretic point of view. *Engr. News*, March 31, *et seq.*, 1888.
- Fuel Gas.** By J. M. Cutchlow, before the Ohio Gas Association. *Am. Manufacturer*, March 30, 1888.
- Harbor Works.** *The New Harbor Works in Antwerp.* By M. Strukel. Description, with illustrations. *Zeitschr. d. Oester. Ing.- u. Arch. Vereins*, 1886, pp. 151-161.
- Iron and Steel, Tests of.** Over 700 specimens of iron and steel given in detail. Taken mostly from guns, shot and shell. Watertown Arsenal Report for 1885. Ex. Doc., No. 36, 49th Cong., 1st Session.
- Least Squares** On some simplifications which may be made in the application of the method of least squares. By Dr. Nell. *Zeitschr. f. Vermessungswesen*, 1887, pp. 454-467.
- Locomotives, Compound.** Gives a method of computing the mean pressures. *Mech. World*, March 10, 1888.
- , *Estrade's High-speed.* An illustrated description and criticism of Estrade's high-speed locomotive. It has six driving wheels $8' 3''$ in diameter, cylinders $18\frac{1}{4} \times 27\frac{1}{2}$, with a weight of 42 tons. *Engineer*, March 9, 1888.

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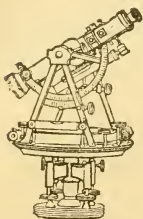
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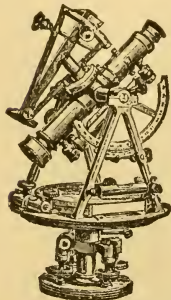
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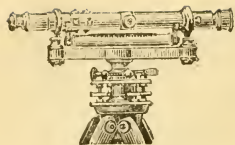
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- , *Indian State Railroad.* Gives brief description, with plan and elevation, of a six-coupled metre gauge locomotive for the Indian State Railroad. *Engineer* March 27, 1888.
- , *Philadelphia & Reading R. R.* Gives outlines engraving of the four classes of new locomotives to take the place of the Wootten locomotives on the Philadelphia & Reading Railroad. *Nat. Car and Loco. Builder*, April, 1888.
- , *Passenger, N. Y., L. E. & W. R. R.* Gives elevation, half-plan and three cross-sections, with brief description, of a high-speed passenger engine for the New York, Lake Erie & Western Railroad. It has two pairs of 68-inch drivers, cylinder 19×24 , and weighs 115,000 lbs., with 78,000 on the drivers. *Nat. Car and Loco. Builder*, April, 1888.
- , *Tests Comparing Radial Motion and Link Motion.* By Angus Sinclair. Gives details of test trips made on the Burlington, Cedar Rapids & Northern Railroad with engines of similar dimensions but equipped with different valve-gear. Gives 38 indicator diagrams. *Nat. Car. and Loco. Builder*, April, 1888.
- Mining, Systems of, in Large Bodies of Soft Ore.** By R. P. Rothwell, before the Boston meeting of the American Institute of Mining Engineers. Describes the system employed at the Dean River mine and proposes working the vein out from the top down instead of from the bottom up. *Engin. and Mining Jour.*, March 10, 1888.
- Mortar. Efflorescence and Impervious.** By Ira O. Baker. Gives reason of efflorescence and discusses its remedy. Also discusses the use of soap and alum to render brick and mortar impervious. *Engin. News*, April 7, 1888.
- Ores, Dressing of Non-Bessemer.** By G. W. Maynard and W. B. Kunhardt. *Engin. and Mining Jour.*, March 31, *et seq.*, 1887.
- Ore-Deposits. Geology of the Aspen, Col.** By L. D. Siver. *Engin. and Mining Jour.*, March 17, *et seq.*, 1888.
- Piles, Supporting Power of.** By Prof. J. O. Baker. Discusses the formula of Mr. Trautwine, and shows its defects. Gives an empirical formula derived by Mr. Hertz from driving of over 400 piles. *R. R. Gazette*, April 6, 1888.
- Planometer, Corade's Rolling.** By Prof. F. Loeber. A description and theoretical study of Corade's rolling planometer. *Zeitschr. f. Vermessungswesen*, 1887, pp. 377-383; 421-437.
- Pumping Engine, Chicago.** The report of Mr. F. W. Gerecke to the Commissioner of Public Works on the condition and capacity of the pumping engines of the water-works. *Am. Engr.*, March 14, *et seq.*, 1888.
- Railroad, Lartigue System.** Gives brief description of Listowel & Ballybunion Railroad, Ireland. It is ten miles long and built on the Lartigue single rail system. Gives cuts of rolling stock and details of roadbed. *Engineer*, March 2 and 9, 1888. *Sci. Am. Supple.*, April 7, 1888.
- Railroads, Journal Friction and Train Resistance on.** An address before the March meeting of the Western Railroad Club by G. W. Rhodes. *Master Mechanic*, April, 1888.
- *Switch, Standard Point.* Gives full detailed drawings of the standard point switch of the Boston & Albany Railroad. *R. R. Gazette*, March 2, 1888; *Engin. News*, March 31, 1888.
- Rail, 85-lb. Standard.** Gives drawing with full dimensions of the 85-lb. standard rail of the Pennsylvania Railroad. *R. R. Gazette*, April 6, 1888.
- Rainfall as influenced by forests.** See Forests.
- Reservoir, Storage.** A description of the building of the embankment of Ashland Basin No. 4, Boston Water Supply, by W. F. Learned, together with the methods used for the mixing and handling of concrete. Illustrated. *Jour. New Eng. W. Wks. Assoc.* December, 1887.

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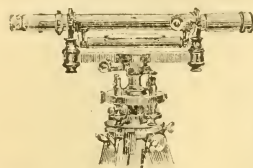
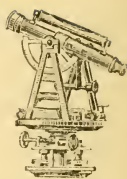


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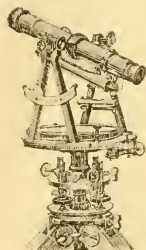
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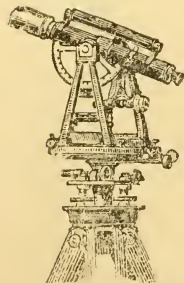
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- River and Harbor Works in Northern France.** By L. Schrader. Interesting description of the works on the lower Seine and Seine, and of the harbors of Nantes, St. Nazaire, Rouen and Havre. *Zeitschr. d. Oester. Ing.- u. Arch. Vereins*, 1887, pp. 130-154.
- River Improvement in Bavaria.** An illustrated article condensed from the *Journal of the Austrian Society of Engineers and Architects*, No. 43, 1887. Shows method of constructing embankment, shore protection and dikes. Gives rule for the proper proportion of depth and width of channel at lowest water line. *Eng. News*, March 17, 1888.
- Riveted Joints.** Details of tests of 96 specimens of O. H. steel plates, 12 specimens of rivet metal, and of 154 riveted joints, made at the Watertown Arsenal in 1885. Report for that year, Ex. Doc., No. 36, 49th Congr., 1st Session.
- Roof Truss.** A brief description with full detailed drawing of main roof trusses of the station of the South Brooklyn Railroad and Terminal Company. The trusses have a span of 147 feet, rise of 30 feet, and 27 feet effective depth. *Engin. and Building Rec.*, March 17, 1888.
- Sewers.** Gives the decision in the case of the New London sewer assessments. The assessments hold good. *Engr. and Build. Rec.*, March 31, 1888.
- Siphon, Automatic Intermittent.** Gives a description of a self-priming siphon for sanitary or manufacturing purposes where a periodical flush is required. *Sci. Am. Suppl.*, March 31, 1888.
- Sinking Funds.** *Formulee derived.* *Jour. New Eng. W. Wks. Assoc.*, June, 1887.
- Steel. Improvements in Open-Hearth Practice.** By A. E. Hunt, before the Boston meeting of the American Institute of Mining Engineers. Gives a good description of the process of making wrought-iron direct from the ore employed by the Carbon Iron Company at Pittsburgh. *Eng. News*, March 24, 1888.
- , **Manganese.** By R. A. Hadfield, before the Institution of Civil Engineers. Two papers, "Manganese in its Application to Metallurgy," and "Some Novel Properties of Iron and Manganese." Iron with from 2.75 to 7 per cent. of manganese is very brittle; between 7 and 20 per cent. of manganese give a very strong and tough material, specimens of which broke with a tensile strain of 65 tons and showed an elongation of 50 per cent. Abstract *Engineering*, March 9, 1888; *R. E. Gazette*, March 30, 1888; *Sci. Am. Suppl.*, April 7, 1888; *Mech. World*, March 10, 1888.
- Street Railroads.** An illustrated description of the Mekarski compressed air car, several of which are now working on a London road. *Engineering*, March 23, 1888.
- Surveying and Geodesy, Literature of, for the year 1886,** by R. Gerke. A complete list of books and papers on these subjects for 1886. Valuable for those desiring to keep posted on this subject. *Zeitschr. f. Vermessungswesen*, 1887, pp. 475-502, 514-519.
- Triangulation.** The field operations of the primary triangulation of the Prussian survey. By Erfurth. General description, outfit, signals. *Zeitschr. f. Vermessungswesen*, 1887, pp. 377-383, 421-437.
- Tunnels, Bottom or Top Heading in.** By C. L. Kalmbach. Discusses the use of top heading and advocates the use of bottom heading. Illustrated. *Engr. News*, March 24, 1888.
- Water Tower.** Gives detail drawings of a tower 100 feet high, built of gas pipe, for the purpose of elevating a 6,000-gallon water tank at San Antonio, Texas. *Engin. and Build. Rec.*, March 24, 1888.
- Water Supply, Tokio, Japan.** By Yeiji Nakahima. Gives a good history and description of the water supply of Tokio, Japan, with map and illustrations of wood pipes. *Engin. and Build. Rec.*, March 17, 1888.
- Water-Works, Boston.** A description, with plan and section, of the Fisher Hill, Boston, reservoir; also plan and sections of the gate chamber. *Engin. News*, March 24, 1888.
- **Consumption and Capacity in 30 cities and towns for the year 1886.** *Jour. New Eng. Water-Works Assoc'n* for March, 1888.

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Water in Japan. *A Description of Japanese Water Supply Systems.* By Prof. W. S. Chaplin. *Jour. New Eng. Water-Works Assn.*, Dec., 1886.

Water in "Great Ponds." *To Whom Does it Belong?* The question argued in favor of the public, as against the riparian owners below. *Jour. New Eng. Water-Works Assn.*, Dec., 1886.

Water. *The Odor and Color of Surface Waters.* A most excellent paper and valuable discussion before the New England Water-Works Association. By Prof. Thos. M. Drown. Gives methods of determination and results of the official examination of the potable waters of Massachusetts, the whole covering 27 pages in the *Jour. New Eng. W. Wks. Asso.*, March, 1888.

Woodite. By Sir Edward Reed. Discusses the use of a new structural material, the base of which is rubber. It appears to be coming into general use in many ways. *Sci. Am. Supple.*, March 31, 1888.

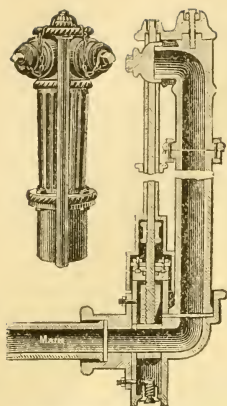
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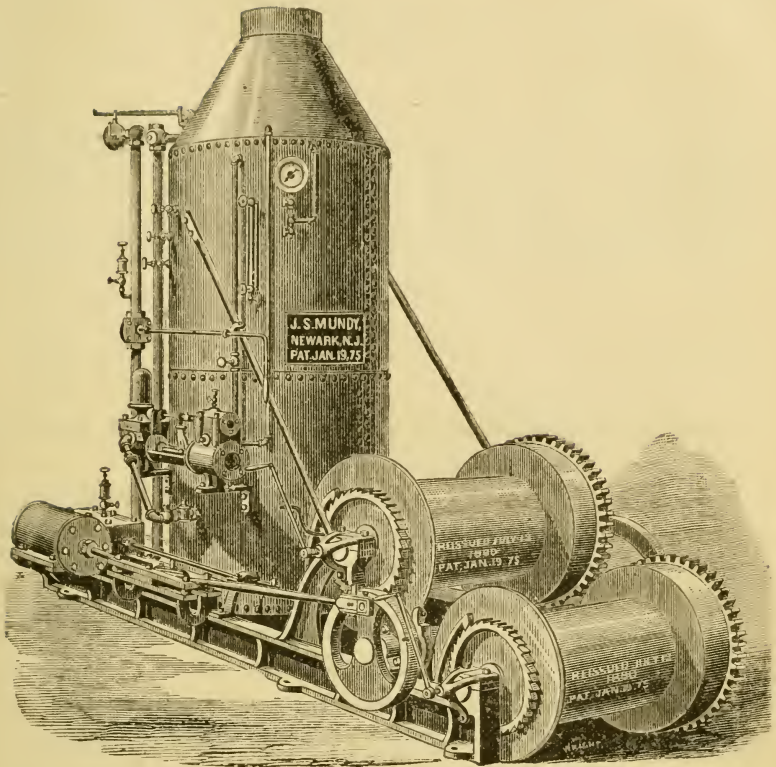
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June, 1888.

No. 6.

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THE SUPPORTING POWER OF SOILS.

BY RANDELL HUNT, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read April 2, 1888.]

It is often necessary for the engineer to prescribe a limit of load, per unit of surface, in designing foundations for structures resting upon soil. In the absence of the time and means to make actual tests of the soil, he must confine himself to an investigation of existing successful structures upon a soil as nearly similar to the one under consideration as he can find. It is the object of this paper then to present a few remarks upon the actual supporting power of soils as deduced from an investigation of the matter from our own observations, and the recorded examples which have been accessible.

It is probably possible to devise a general mathematical formula which would be applicable to the supporting power of any soil, but as such an expression would necessitate our knowing so many particulars as to the character of the soil, such as its weight and natural slope, that we could judge of its actual strength fully as well without applying it. At any rate, we shall confine ourselves to-night simply to the practical side of the matter.

The Supporting Power of Clay.—The supporting power of clay is very variable and depends in a large measure upon the variety, and upon its degree of saturation with moisture. In the roadbeds of railroads, when the "surfacing" has been done with clay, a smooth, hard bed, unyielding and with far greater supporting power than would be required, is always found in dry weather. It becomes very compact, so much so that it is impossible to press the point of a walking cane into it. But after a drenching rain, all conditions change, and the roadbed becomes a mass of mud, into which the ties are pressed down and the clay bulges up between them.

We mention this simple example of dry and wet clay because it is familiar to most of us, and shows clearly the effect of too much moisture in such soils.

The clays vary considerably, however, in their chemical constituents, and are affected thereby in the degree to which they absorb moisture. Certain deposits are known to be compact and hard, with a high supporting power, while others are in the condition of a plastic material, easily compressed. But its chief characteristic which renders all clay more or less unstable, when regarded in the light of a foundation, is its known property of retaining water once admitted to it and its softening propensities, which gradually take place as the amount of water increases.

The stiff blue clay deposits of London are celebrated, as much for the numerous failures of the bridges and other structures founded on it, as for any other reason.

Old Westminster Bridge had probably about $5\frac{1}{2}$ tons to the square foot of foundation, and failed.

Black Friar's Bridge had about 5 tons and appeared to be stable for many years, but ultimately settled very badly.

New London Bridge was built in 1831 and founded upon piles, upon which as much as 80 tons per pile was imposed. Of course, it has settled—in some places as much as a foot. The pressure per square foot of the entire foundation of this bridge is 5 tons.

When the new Westminster bridge was built the load per pile was reduced to about 12 tons, while the load per square foot of the entire foundation was reduced to 2 tons. I find no record of this bridge having shown any signs of settlement.

Robert Stevenson* attempted to load a stiff hard clay with 5 tons per square foot. He was building some high bridge piers at the time, but before they were completed serious settlements took place, and he decreased the amount per foot by making his foundation of greater area than first determined upon. He also built a large chimney which failed, and then constructed another, at Newcastle-on-Tyne, with only $1\frac{1}{2}$ tons per square foot of foundation, which was successful. Both these chimneys are described as being founded on hard compact clay.

The subsoil of the vast valley of the Red River of the North, is a bed of clay, which varies in depth from 80 to 125 feet—a bed of sand and gravel usually being found underlying it. This clay is generally of a yellowish color and appears more or less hard and firm in proportion to the amount of moisture contained in it. Chemically considered it has a large amount of carbonate of lime in it, as can be seen from its action when treated with acids; and when freshly opened up to view in a place where free from much moisture, appears about of the consistency of marl.

In 1881, at Fargo, Dakota, a brick building, of four stories in height, including a basement story, was constructed upon a concrete foundation. The pressure per square foot upon the clay was at no place greater than $2\frac{1}{3}$ tons, and was probably even less than this amount. The building showed a certain amount of settlement each season, until the third year after being built one side of it suddenly commenced to crack, and settled a foot or more in a single day, becoming so dangerous that the occupants were compelled to abandon it. The side which had failed was immediately torn down, a new foundation of broader dimension

* Trans. Am. Soc. C. E. Vol.

put in and the wall reconstructed. The load per square foot on the clay of the new wall is about $1\frac{1}{2}$ tons, and, as far as the author knows, has remained intact. All along the side of the wall which failed was an open area way which was very imperfectly drained, and we are inclined to think was the cause of the clay becoming softer than it otherwise would have been, for the other three sides of the building, while showing more or less settlement, yet remained comparatively in good condition.

In the city of Cleveland, Ohio, many heavy structures have been founded upon clay deposits, and one or two notable ones have shown serious settlements. In the new Central Viaduct, now being constructed, and the foundations of which were described in the JOURNAL OF ASSOCIATION OF ENGINEERING SOCIETIES, the pressure per square foot of foundation on those piers and abutments which rest directly upon the clay has been limited to from 1 to 1.7 tons. The abutments which exert the largest load mentioned are described as resting upon "a mixture of blue sand and clay, with some water," while the piers giving a load of but 1 ton per square foot rest upon a "plastic blue clay of various degrees of stiffness, mixed with fine sand."

When clay is mixed with other materials, as coarse sand and gravel, its supporting power usually largely increases, being greater in proportion as the other materials are in excess, up to the point of forming a concrete mass, in which the clay is the cementing material, and in just sufficient quantity to bind the materials together. In this condition we often find the clay in an indurated state, and the hardness of the mixture—commonly called "hard pan"—is proverbial. Such soils are safe for heavy loads, approximating that of the softer rocks.

Brennecke, in his book on foundations, mentions a large chimney with a load of 6 tons per square foot on hard clay. This is an extraordinary example, and we are inclined to think, though no further particulars are stated, that it was upon some such hard mixture of clay and gravel as mentioned. At any rate it would be a bad precedent to follow in loading beds of pure clay.

The Washington Monument is founded upon a layer of clay and sand. When the shaft was up 150 feet an investigation showed that the foundation was entirely inadequate upon which to complete the structure—a committee of United States Army engineers reporting that such a soil should never be loaded above 10,000 pounds per square foot. The foundation was therefore made heavier and larger, and the shaft successfully completed with a height of 555 feet. Colonel Casey, the engineer in charge, reports the pressures upon the soil as nowhere exceeding nine tons per square foot, and less than three tons per square foot near the outer edges.

The settlement of the monument during the repairs to the old foundations was about two inches, and afterward a further settlement gradually occurred during construction of two inches more, making a total of four inches. If the load per square foot on the soil reaches the amount of nine tons, it is the heaviest load upon such a soil which we find any record of, and we think the doubts expressed by different persons as to the ultimate stability of the monument entitled to careful consideration.

Supporting Power of Sand.—Foundations on coarse sand and gravel are usually successful, particularly if free from the action of running water, and structures, proportioned in accordance with any ordinary rules of good construction, are hardly likely to have an area of base which will not be sufficient to limit the load per unit to the safe carrying capacity of the soil. Coarse sand deposited in beds has usually a high supporting power, but the coarseness alone is not proof positive of this, for it also depends somewhat upon how it has been deposited. On beds of sand made artificially, as is often done for foundations, the dry sand loosely thrown down does not form a compact mass, such as is desirable, and a certain amount of compressibility will exist.

In some experiments made in France with river sand, it was found that by pounding the sand in thin layers its density could be increased one fifth, and that there still remained about 20 per cent. of voids which could be notably reduced by simultaneously treating the sand with water, while the sumping down took place. The compression was exercised in these experiments by means of hydraulic presses, and the result obtained that river sand treated as above would resist up to pressures of 1,420 lbs. per square inch.

Water is the chief agent which makes the particles separate and draws them into the voids of the mass, and is invaluable in all works of embankment in which solidity is required; but it must also be well drained off, because if the original amount should remain of course the mass of earth would continue in a semi-fluid state.

Mr. McDonald, in constructing the iron ocean pier at Coney Island,* assumed that the safe load per square foot upon the flanges of the iron disks, which were sunk into the sand, was five tons. But many of them really support as much as 6.3 tons continually and are subject to occasional loads of eight tons per square foot, which they appeared to sustain without settlement.

The foundation of the large chimney of the New York Steam Company,† was made of concrete resting directly on the sand of the old beach, which had formerly extended to this point. This sand was quite fine, with pockets of gravel, and containing at a few places some stone. The sand was thoroughly saturated with water, and would flow when disturbed or undermined. The load per square foot on this material was to be four tons, but before more than one third of this amount was placed upon it, slight settlements occurred which were not uniform. After the structure was completed slight cracks appeared, but not sufficient to cause any material damage.

In contrast with the loading of the partly unstable sand of this chimney, may be mentioned the loads which were imposed upon a clean, coarse sand in the foundations of the Pacific Mills chimney,‡ at Lawrence, Mass. Here the sand was inclosed by tight sheet piling, and only 1.83 tons per square foot placed upon it.

The anchorage of the Brooklyn Bridge rests upon sand, with a pressure of about 4 tons per square foot. The Nantes Bridge, constructed in

* Trans. Am. Soc. C. E., Vol. 8.

† Trans. Am. Soc. C. E., Vol. 14.

1863, and founded on sand, has a pressure of 6.73 tons per square foot, but has settled somewhat.

The safe loading upon the sandy soil of Berlin is generally taken at about 2.3 tons. Brennicke describes this sand as being comparatively loose, but likewise mentions its having been successfully loaded up to 4.1 tons per square foot.

When sand is mixed with other materials, such as clay or loam, which have the power of retaining water, its supporting power grows less, and proportionally more so as the sand becomes finer and loses its sharpness. Of such a nature is the commonly-called "quick" sand, which really occupies a position between pure sand and pure clay, being a mixture of them both. Pure clay is composed of alumina, water and silica, and in proportion as the silica is absent the more water will it hold. This is the material which, when mixed with the very fine and rounded grains of sand, makes it "quick." Deposits of such are often found, which through long draining have lost all the water, and which appear dry, and loose, and easy to excavate or handle, and generally of a whitish color.

If we could keep such deposits absolutely free from saturation with water, we could trust it with moderate loads. Its weight is less than either good sand or clay, running from 70 to 90 pounds per cubic foot.

At the foundations of the Capitol at Albany Mr. W. J. McAlpine describes some of the material as being quicksand without the water. Experiments made in the soil of this foundation showed that under a weight of two tons per foot no perceptible displacement occurred; and at about five tons the surrounding soil was forced upward. It was endeavored to place no more than two tons per foot upon the soil with the completed building, and great pains were taken, by means of spreading gravel six inches deep over the whole area, and inclosing it in a puddled wall, to keep the character of the soil from changing. These foundations have partly failed, and serious cracks have appeared in different parts of the structure. We wish here to call your attention to the remarks which we shall make later on, upon judging of the supporting power of soils by limited experiments upon the same. We have not been able to find any complete account of how they were made in this case.

We find recorded by Debauxe, a case of founding upon a loose, watery sand, partaking somewhat of the nature of quicksand, in which the load per square foot was 1.8 tons. The sand is described as being of a sirupy consistency, and after endeavoring to excavate it without success, further than getting out about three feet in depth, they filled back into this partially excavated hole with dry, coarse sand, placed a bed of *béton* upon it, and completed the structure, which was a bridge over the canal of the Sambre à l'Oise, for the railroad from Busigny to Herson in France. No after settlement occurred.

This method of treating quicksands with coarser sands and gravel, appears to have been of much service in many cases. Trautwine records an example of its successful use in making a foundation over quicksand, for the brick aqueduct for supplying Boston with water.

Supporting Power of Soft Soils.—In speaking of soft soils we generally mean those which are referred to as being compressible, though really

EXAMPLES OF FOUNDATIONS ON SOILS.
(In tons of 2240 lbs.)

	NAME OF STRUCTURE.	Date.	Engineer.	Kind of soil under foundation.	Pressure per sq. foot (tons).	
1	{ Central Viaduct, Cleveland, Ohio..... }	1887	C. G. Force.	Blue clay.	1.0 to 1.7	{ The blue clay of the foundation is mixed with some sand and water. (Journal of Ass. of Engr. Soc., Vol. VI., No. 6.) }
2	{ Bridge on R. R. Busigny to Herson, France..... }	..	....	Unstable sand.	1.8	{ Over the <i>Canal de la Sambre</i> . (Debauxe.) }
3	{ Arches on R. R. Busigny to Somain, France..... }	..	....	Yellow sandy clay.	2.1 to 2.8	{ (Debauxe.) }
4	{ Chimney at New-castle-on-Tyne..... }	..	R. Stevenson.	Compact clay.	1½	{ (Trans. Am. Soc. C. E., Vol. II., page 287.) }
5	{ Kuilenburg Bridge, Holland..... }	..	....	Compact sand.	2.3 to 2.9	{ A slight mixture of clay with the sand. (Debauxe.) }
6	{ Chimney N. Y. Steam Co.... }	1882	C. E. Emery.	Wet sand.	4.0	{ Sand was not very compact; some slight settlement. (Trans. Am. Soc. C. E., Vol. 14, p. 180.) }
7	{ Viaduct, Point-du-Jour, France..... }	..	Bassompierre Sewrin.	Coarse gravel.	4.4	{ (Debauxe.) }
8	{ Brooklyn Bridge (anchorage). }	1882	Roebbing.	Sand.	4.0	{ Some settlement has taken place. (Gaudard.) }
9	{ Brooklyn Bridge, N. Y. Pier. }	1882	"	Compact stony clay.	5.5	
10	{ Nantes Bridge, France..... }	1863	....	Sand.	6.78	
11	{ Gorai Bridge, Lock Ken Viaduct Bordeaux..... }	..	..	{ Compact sand and gravel. }	7.36 to 8.17	{ (Gaudard.) }
12	{ Washington Monument..... }	1884	U. S. Engineers.	Clay and sand.	3 to 9	{ Slight settlement during construction. (H. R. Mis. Doc., No. 8, 48th Cong., 2d session.) }

this is more or less of a misnomer, for they are regarded as being the more compressible in proportion to the amount of water they hold, and yet we know water is practically incompressible. Debaure, in his excellent work on foundations, makes this distinction clear, and classes such soils as "*mobile*," movable, which in itself is a true definition of their characteristics.

The alluvial mud of many rivers gives us the best example of soils of this kind, and in this country, as in general in most others, the soft soils are usually found at the lower end of rivers flowing through valleys of considerable width, and emptying into the sea or large lakes, where the force of their currents is checked by the larger body of water, causing the detritus held in suspension to be deposited in beds of greater or less thickness; or by overflowing their banks and spreading far and wide throughout the valley the waters lose sufficient velocity to carry the suspended matter further.

An example of the greatest magnitude, of such formation, is seen in the country adjacent to the lower Mississippi, and much of the State of Louisiana has been formed in this way. Here is to be found the "*prairie tremblante*," or trembling prairie—vast stretches of land composed of a semi-fluid, mud subsoil, overlaid by a mass of decayed vegetable matter, and which, tied together by rootlets, forms a more solid, but trembling, crust.

It is impossible, of course, to solidly found any thing upon such soil; but rather must any such attempt be regarded as a problem of flotation in a muddy liquid. Yet we are often called upon to construct railroads, bridges and buildings in soil but a trifle more solid and homogeneous.

The supporting power of all soils is of course dependent more or less upon the depth at which the foundation is made, and in the alluvial soils such as we are now considering, this is of more importance than in other kinds. We have not time at our disposal, in this paper to enter into this matter more fully, and in our remarks we have treated upon the supporting power of soils as we generally use them and not much affected by depth.

The softer clays really belong to and should be treated in the same manner as the soft alluvial soils to which we are now alluding.

The actual supporting power of such soils can hardly be given in figures which can be of much real value. In the city of New Orleans, for instance, almost without exception, we find recorded the serious settlement of all the larger buildings and structures, which have been founded directly upon the alluvial soil, and in many cases the load per square foot is much less than a ton. From some experiments made in India in alluvial soil, the safe load per square foot is given as 1 ton; while Sir Charles Fox* finds it to be only 1,680 pounds for the soil which he tested.

Experiments to determine the weight which can be safely placed upon soft soils have often been made, but are not generally of much value, unless the area of soil tested is of about the same extent as the base of the foundation to be placed upon it. This was very clearly shown in France, some years since, by a series of experiments made in the soft alluvial soil of the valleys of Vilane and l'Oust.†

* Clemann's Railroad Engineer's Practice.

† Annales des Ponts et Chaussées, 1864.

A number of small piers of masonry, 6.56 feet square, were built at different points, and made of such a height as to give a load per square centimeter double that of the large embankment, which it was the intention to afterwards construct. It was supposed that these piers would settle deep into the mud, but they really settled a comparatively small amount, while the embankment, covering a great, broad area of base, but exerting a pressure per square centimeter of only one-half that of the piers, showed in all cases very much greater settlements.

The explanation was simple: if a small pier, with a square base, is pressed down into the soft soil, the frictional resistance against the sides of the compressed ground is proportional to the length of these sides; while a square pier of, say, double the width, would experience a frictional resistance just twice that of the first pier. In other words, this resistance is directly proportionate to the *length* of the perimeters of the bases. But the *area* of the base of the second pier is four times that of the first, hence we see that, with an equal pressure per square unit of base, a small pier would have much more resistance to overcome than a large one, and that one would be at fault to take as a correct measurement of the supporting power of the soil the results obtained from loading but a limited area. Experiments upon the soil in New Orleans, made in 1851 and 1852, and which are recorded in *Van Nostrand's Magazine*, Vol. 27, showed analogous results.

Stated then as a proposition: *The supporting power of soft soils is greater in proportion as the loaded area is limited, or, conversely; large areas of soft soil will not support as much weight, per unit of surface, as more limited areas of the same soil.*

This principle is most important and should not be neglected by engineers designing foundations. It is applicable to the supporting power of bearing piles, and hence any formula for the same which does not make a distinction due to different sectional areas of the piles, is incorrect in theory.

RAILROAD LOCATION—FIELD PRACTICE IN THE WEST.

BY WILLARD BEAHAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 4, 1888.]

To know what location is best for a railroad is one thing; to be able to make that location is another, and a very different thing. In other words, it is one thing to be a good locating engineer; it is another thing to be a good chief of a locating party. To be the one does not imply that you are therefore the other, even in point of knowledge. Within the limits of this brief paper is no allusion to the theory or science that is the province of the locating engineer. That field is too broad, and is as yet quite unmapped country to me. It has been said that those who have traversed it the most are most silent about; while those whose steps have scarcely gone inside its boundaries are most voluble concerning it.

It is my purpose to touch upon the subject of railroad location from that lower plane, the standpoint of a chief of a locating party. It is my

wish to call some little attention of the members present to this subject, and so gain the appreciation of at least younger men, who in so large numbers look to the location of our growing railroad system as a promising field for their future work. From these younger men who may learn in time to become able chiefs of party, it is hoped that, through study and experience of higher matters, a generation of railroad engineers will develop among whom we may find in the future a few locating engineers of sound theory and able practice.

For this paper it is assumed that all statistics as to direction and volume of traffic; districts or cities to be passed through: assistant engines to be used, with all kindred topics, have been foreseen and a decision reached. The company building the line, whose will is voiced by its executive board, chief or locating engineer have issued their instructions. The line is to start at a stated initial point: pass through other points, towns or mining property, and end at a stated terminus. Under certain relative proportions of obstacles met, these instructions are qualified. On the route a certain maximum gradient per station of 100' will be used on tangents, and the equivalent maximum gradient on curves. A certain least radius of curvature will be preferably used, and a certain other, and less, radius be in no case passed. The length of this line in excess of least distance through controlling points must be economized, and the incurring of heavy grading not unavoidable must be shunned; all in a degree usual with that company or class of road.

With a full and clear understanding of what his employers wish to do, it now rests with a man employed as a chief of locating party to organize and equip that party, and make all future reconnaissances, preliminaries and location. We pass over all matters pertaining to organization and equipment; that structure too often founded on whim and circumstances, in which the largest room is the room for improvement.

There are two distinct systems of railroad location. From these two or their modifications the chief of party must choose, viz.: 1. Running with his party a preliminary line on all routes or combination of routes offering any promise throughout the belt possible to occupy. Then from a comparison of their maps and profiles, select the route for the located line. This is the method of "reconnaissance with full party."

2. Topographically surveying and mapping the entire belt of country possible to occupy and then making a paper final location on this map. Then run in this platted location on the ground. This is the method of "office location."

The first method is the one formerly used in a great degree in this country, the second is now used in the old countries, I understand. Each system has its advocates, in a degree, at least. Briefly stated, it appears to me that the objections to the first system are, that it is unsafe and expensive. It is unsafe because you cannot know but that there may exist a better route than any you have occupied, even when you think *all* have been occupied. Then, too, it is possible to follow an excellent route in such a careless way as to condemn it. It is expensive because it usually involves the running of much preliminary line that a close recon-

naissance by any one would show to be worthless. Again, it always involves endless backing up. A successful chief of party is known by the amount of backing up he never needs to do. It is the transitman's method. It is slow; it is lazy. It is rough guessing without compass or other aid to map the way in advance. It will never disappear as a method, for any man can use it, and draw his salary and give less equivalent for it than by using any other method.

The objections to the second system are that it takes too much time and costs too much. It is a topographer's method; and it is an office method. No scale is as large as nature's scale; hence—office location is handicapped as against field location. It is unnecessary in easy country; in difficult country it takes a better railroad engineer than a topographer to apply it safely, and on a reasonably narrow belt which will always be found to contain the best final location. A modification of this second system is sometimes resorted to by painstaking chiefs of party when they encounter very difficult country for a short distance. It is the student's method, and will be followed by those of less experience in such field work. It appears to me that used on the difficult short portions of a line in connection with an earlier personal reconnaissance of the entire line by an experienced chief of party, much chaining and consequent cost could be saved where it is wished to merely examine a route thought of for future lines.

Instead of following strictly one of the two systems mentioned for railroad location, a rare occurrence in practice, the following modified one is suggested as better, and to it your attention and criticism is invited. The chief of party, having secured the best large-scale map of the region to be passed through, takes his letter of instructions and draws accurately and sharply upon his map a straight line from the initial point to the first controlling point in instructions; from thence straight lines through the successive controlling points to the terminal point. This is a broken right line passing through the primary controlling points. With this map, a pocket prismatic compass, a good hand level, an aneroid, and field glasses, he should then ride over the country, keeping as closely as possible by compass or section lines to the pencil lines on the map. He must note carefully how the topography lies with reference to that map, sketching the details. Elevation of main divides above drainage crossed, with estimate of distances apart, are important. He had better ride over the entire line. He *must* ride to the first primary controlling point beyond the initial point. On his return he should check by repetition his previous aneroid readings. He should especially notice, at points where his pencil line passes over impracticable country, on which side of that line there offers a feasible route *nearest* the pencil line. He must never forget that this pencil line being the shortest line is therefore the cheapest and best line, other things being equal. His finally located line, whenever it is found on that pencil line, needs no excuse for its being there when obstacles on it are not in sight. But if at any point his finally located line is not on that pencil line, he must be able to give good reasons for it not being there. This philosophy of direction is plainly self-evident, but not one-fourth of the chiefs of party in this country to-day realize the force of it. Of course, the

object of his first reconnaissance is to find secondary controlling points. These are topographical points, and before returning to the initial point the chief of party must find the first of the secondary controlling points to be passed through. From that point back to the initial point he must sketch the country, topographically marking natural objects and indicating plainly on this sketch where the line should, in his judgment, be run from the initial to the first of the secondary controlling points. He gives this sketch to the topographer of the party, explaining it fully, and bearing in mind that the topographer must be able to recognize any point from the one back of it.

Natural objects, or drainage, crossings of streams or saddles on divides, needle bearings, angles to be turned, horizons shown in outline, or a gradient to be used are among the methods of indicating the route. Details must often be left to the topographer and ample discretion allowed him. The topographer has charge of the line party during the day; points out the route by the aid of the sketch and the line is so run. He takes usually wide general topography in easy country, and narrow close topography in the difficult country. He takes only that which he thinks necessary for preliminary use. At times he must take minute topography; at times he may take very little. This man must be an engineer of experience. On preliminary running this method is followed from day to day. Each night the chief of party furnishes a sketch and description to guide the topographer for the whole of the next day. Each day the chief of party is steadily on horseback, and with his map and pocket instruments making reconnaissances ahead of the party. He must at all times have selected the most promising route, and the details marked out, for ten or fifteen miles ahead of the party. He must ride constantly, and except an unusually difficult point be met, he must not be within sight of any of his party in daylight. He must find all routes of any promise whatever, and fully examine them all. He must determine in advance where more than one preliminary is needed, and why. He must do some guessing, but never let it pass without verifying it with some instrument. He must be able to tell with some certainty whether a route is feasible, or his alignment or profile will be too difficult. But, if he cannot, as a rule, tell whether a route is reasonably practicable under his instructions without running a line in it with his party, he must resign, and had better go as topographer on some party whose chief has a better eye and judgment.

The preliminaries may be carried through to the terminus or may stop at a controlling primary point. To stop at a secondary controlling point is not so safe. I prefer to stop in ten or fifteen miles, to run all second or modified preliminaries, and then to start locating for a short distance, alternating the one with the other. One can do better work on location when the country and the preliminaries in it is fresh in the minds of all. It may occasionally involve abandoning located line, but I have never lost any. It is safe if you have made a correct and far-reaching reconnaissance. This method always presumes that. Each night the transit line of the preliminary is platted to a scale of one inch to one thousand feet on a continuous roll, and the topography penciled in. The profile is platted and a grade line laid by the chief of party. Before the party

has run the last day on preliminary the chief of party must walk over the adopted preliminary line for a distance out from the initial point sufficient for one day's location. He must mark on the map and profile which he carries with him for that purpose where the located line should be placed. Usually the transit line can now be drawn quite closely on the map. The topographer with the aid of these notes, or map and profile, now starts the location, following these directions with discretion. He drops the location when within a safe distance of the end of the present preliminary. The chief of party must examine the located line in the field and see that no errors have occurred. The transit line, topography and levels are platted on location each night, grade line, openings, classifications, etc., noted carefully on profile.

The preliminary is now resumed. In difficult bits of country a first preliminary is run with very full and minute topography, and side heights taken well out with the level where slope changes. This part of the line is platted separately to a scale of one inch to one hundred feet. A grade line is then to be assumed if it be a difficulty through gradient: or an alignment is to be assumed if it be a difficulty arising through alignment. The preliminary as modified on paper must now be run, after which the line can usually be located. While every unusual difficulty is a problem by itself, as a rule, I have found the above plan successful and rapid. In running the modified preliminary where the difficulty arises from gradient the level must be run ahead of the transit to find points for the transit's course. Hand levels can be used on this work instead, but our instrument makers have given us no hand levels as sensitive as good nerves can hold readily. We need hand levels whose bubbles have longer radii. Our prismatic compass is in advance of the hand level in point of sensitiveness and also in portability. In fair weather, by checking back my aneroid barometer has never misled me, and is an aid. The adverse reports of others who have used gradienters on their transits have deterred me from feeling sure of their value. They are reported unreliable. They would aid the topographer, and I should like information from those who have used them many months on railroad location. If any present can inform me as to the practicability of ribbon chains—sometimes called band chains—for such work it would be information quite appreciated. Link chains wear too much, and on curves their accuracy is less than the transit's sighting and centering. We must make progress in this direction. A ribbon chain must be thoroughly tried.

This system of railroad location has been described as clearly as is easy within the limits of this paper. I trust others will suggest improvements, or a better and entirely different structure. This method was taught me in sharp outline by valued superiors. Twelve hundred miles have been run by me in this way for one company, and my efforts and those of excellent assistants have always been to devise improvements. No space offers to discuss details. Some believe that a system should be devised to enable any novice to safely locate a railroad. Is such a system economically possible? Others think that the chief of party described is a man rather hard to find. But to this my reply is that the system grows such men. A graduate of any of our better engi

neering schools, starting as level rodman, becoming in turn levelman, transitman and topographer has grown to a position as a chief of a preliminary party. His training has cost nothing to any one, either in salary or blunders; and he has then the very pleasant satisfaction of knowing that he has been a first-class man from start to finish, need never feel a shaky foundation under him, and commands respect of subordinates.

The respect of subordinates is harder to get, and of more value than the respect of superiors—to which it is the only safe stepping stone. This system is not a one man system.

With a good education, hard work, sturdy health, good habits, good eyes, study, judgment, and that summation of stanch qualities termed manliness, any boy can grow to be a successful chief of locating party. Talent and inspiration I must leave out of the account, as I know nothing of them. That this system, when successfully used, is rapid is evident. If it be rapid, it is therefore cheap. A system based on ample reconnaissance by an experienced man should be safe. It requires faithful, intelligent work on the part of all members of the locating party. It seems to me to possibly resemble the system of the near future for the western railroads of this country.

EULOGY UPON THE LIFE OF CHARLES LATIMER.

PRONOUNCED BEFORE THE CIVIL ENGINEERS' CLUB OF CLEVELAND, APRIL 24, 1888, BY WILLIAM HENRY SEARLES, C. E.

It is with strangely mingled feelings that I attempt to fill the place assigned me in the exercises of this memorial occasion. For no one would I more gladly do a service, in life or in death, than for our lamented friend and brother who was so lately in our midst full of life and ardor. There are those present, however, who have known him much longer than I, who, by their daily duties, were brought into more frequent contact with him, and who therefore may be able to speak of him more fully than I can do: yet I would not lose this opportunity to add my testimony to his worth, and I count myself second to none either in affection for the man or in admiration of his noble character.

Mr. Latimer was in several respects a remarkable man. No one could converse with him for any length of time without being impressed with the feeling that he was a man of no ordinary ability. He had a marked individuality and force of character which soon impressed themselves on any company. He had the courage born of well settled convictions, which made him bold to express his opinion regardless of the views of his auditor. His strong statements and evident sincerity were well calculated to silence opposition, and sometimes to make the listener doubt his own information on the subject. Yet combined with this firmness of speech was such gentleness of manner that no one could take offense. He was a fine exemplification of the old motto, "*Suaviter in modo, fortiter in re.*" He made it evident in any argument that he was combating the idea, not the man, and that his sole motive was to defend the truth as it was presented to his own mind, and so, though he might not always

make a convert, he was sure to win a friend. It is not uncommon for his acquaintances to remark that though they might not agree with Mr. Latimer in all his views, they always admired his candor, and felt the warmest personal regard for him.

Mr. Latimer entered heartily into whatever he undertook. There was nothing of listlessness nor indifference about him. Amid the multiplicity of affairs which divided his attention he gave to each in turn that closeness of thought and earnestness of purpose which mark the successful man. Possessed of a sound physical frame, a rugged constitution and a strong intellect, his lofty soul directed all the energies with which he was endowed to noble and honorable purpose. Had the same energies been devoted to selfish ends, how different would have been the result to himself and to the world! But selfishness seemed to form no part of his being. He studied rather how in all things he might benefit those about him and contribute to the common welfare of mankind.

Ruskin has said, "It is physically impossible for a well educated, intellectual or brave man to make money the chief object of his thoughts; as physically impossible as it would be for him to make his dinner the chief object of them. All healthily minded people like making money—ought to like it, and to enjoy the sensation of winning it—but the main object of their life is not money; it is something better than money." This truth was well illustrated in the character of the man whose memory we are met to honor. Like Prof. Agassiz he might well have said: "Money! I have no time for making money."

As a civil engineer Mr. Latimer was connected with various railroads both North and South. The education which he gained at Annapolis as naval cadet did not specially fit him for railroad service, but his dauntless energy, close observation and retentive memory enabled him to fill up for himself in the school of experience whatever was lacking in his theoretical training regarding railroad work. After serving his country in the navy for thirteen years of peace, he resigned his office and began his career as a civil engineer at the lowest round of the ladder. This was in 1854. He gradually rose, however, and during the late civil war he served as assistant engineer in the United States Military Railway Service, doing much important work in Kentucky and Tennessee.

Subsequent to the war, after a short engagement in command of a steamboat on the Mississippi River, he connected himself once more with railroad work, in which he continued up to the time of his death. He was engaged successively upon four or five Western roads either as principal assistant or chief engineer. In 1873 he accepted the position of assistant engineer on the Atlantic & Great Western Railroad, but was speedily promoted to principal assistant, and after one year was made chief engineer. He held the latter position until two years ago, since which time he was consulting engineer to the same road, now known as the New York, Pennsylvania & Ohio.

His success as an engineer was largely due to his natural ability to cope with men and affairs, joined with a good common sense, a quick judgment and a resolute purpose to do the right thing at all hazards. His intuitive judgment of men made him fortunate in the selection of those who were to serve under him: his training in the navy and army made

him a strict disciplinarian, while his large-heartedness and love of justice taught him how to use the hand of steel in the glove of velvet.

During his connection with the last mentioned road he was for most of the time quite untrammelled in the conduct of the engineer department, so that the remarkable improvement in the character of the road-bed, track and engineering structures which took place during his administration can be justly ascribed to his personal and professional skill.

He inspired his men with a love of their work for the work's sake, and with an enthusiasm for himself, their esteemed and honored chief, that was indeed exceptional. He instituted a "Roadmasters' Meeting," which convened annually in his office and held an all-day session. A list of subjects pertaining to maintenance of way was prepared in advance, which was reported upon and earnestly discussed by the assembled roadmasters, the reports and discussions being afterward published in full in pamphlet form. He thus secured the interest, promoted the experience, and stimulated the ambition of his subordinates.

Mr. Latimer had no sympathy whatever with the autocratic method of government now so common in railroad affairs. He thought something more than prompt payment of wages was required to secure the best service of good men. He believed in the most humane and considerate treatment of all employes, and ascribed to the lack of such treatment most of the strikes, so deplorable in their consequences, that have occurred upon our railroads in late years. His views upon this subject were very decided, and were fully expressed in a paper read before the American Society of Civil Engineers in convention two years ago. He advanced the idea that it might become necessary in the future for the general government to control the railroads, not merely by an interstate commerce law, but by taking the entire management of the roads into its own hands, as it has done with the post-office and as it is likely to do with the telegraph system.

As an inventor Mr. Latimer distinguished himself by producing what is now known as the Latimer Bridge Guard, an arrangement upon the track by which a derailed car is made to replace itself on the rail before reaching a bridge. This device has been adopted and is in use on many roads. He was also interested in originating a mechanical method of handling ore and coal, raising them from vessels and transporting them to piles on the piers by steam power. This is an important invention which has since developed into a business of large proportions. But Mr. Latimer's inventions and improvements were all made in the course of his duties as chief engineer, and for the benefit of the road he was serving and without expectation of personal reward from their general introduction.

In his earlier years he discovered that he possessed a magnetic or mesmeric power over others which he could exercise at will. It was not even necessary for him to resort to the usual passes and other manipulations. —the simple concentration of his own mind for a short time would be all sufficient to gain control of another person. He practiced this to some extent while in the navy for the entertainment of his comrades, and sometimes would convince even the most skeptical man by bringing him completely under mesmeric control without the knowledge or con-

sent of the doubter, until the latter found himself in the toils. In after life Mr. Latimer abstained from the use of this mysterious power on conscientious grounds. He held latterly that the practice of mesmerism ought to be prohibited by law, inasmuch as it gives the operator an unwarrantable control over the person of another.

Quite akin to mesmerism is another power which he possessed in a remarkable degree, and which gave him considerable notoriety, namely, the power of detecting unseen elements in the earth by the so-called divining rod process. This faculty has been successfully employed by individuals, some of them very distinguished men, in all ages and among all nations of the world. It seems to be primarily a mental power. The mind seems to go out in search of the desired element. If this be not found where sought no sensation ensues, but if present, even though at some distance from the person, he at once feels certain sensations, differing with the individual it may be, which assure him of the success of the search. The divining rod is any simple instrument used to give evidence by its motion of the presence of the substance sought. There is no virtue inherent in the rod itself—it may be composed of any material and may have a variety of forms, though a forked shape is usually preferred. If the motion of the rod is communicated to it by the operator it is done unconsciously, and as a rule only when his mind receives the impression of the substance sought in the ground.

Like many other occult phenomena, the results of this practice have often been ascribed, by those unfamiliar with it, to self-deception, charlatanism, and the like. But it would be unworthy this enlightened age to dismiss the subject in such a cursory manner. Certain it is that no material theory will account for the facts in the present state of our knowledge. But in this day of multiplied faith cures and the triumphs of so-called Christian science, we must no longer seek to explain all physical phenomena on a physical basis. We must admit not only the supremacy of mind over matter in a general way, but also the power of mind, or intelligence, or spirit, to act in its own way upon matter outside of the personality of the operator under certain conditions.

Mr. Latimer was remarkably successful in searching not only for water but also for gold, silver, iron, coal and other minerals. He was not only able to detect the mineral beneath a given spot, but also to trace the vein as far as necessary and to determine its limits literally, so that it might be mapped out; also to determine the depth from the surface at which the vein occurred, and the thickness of the vein. Where there were several strata superimposed, as in the coal measures, he was able to give the depth and thickness of each with remarkable accuracy, his figures being afterward confirmed by actual borings. The proceeds of the mining operations undertaken by his advice have amounted to hundreds of thousands of dollars. He declared that he had discovered a heavy pressure of natural gas at a depth of 3,500 feet below the Newburgh quarter of Cleveland. He made the divining-rod test repeatedly and at different times, and always with the same result. A well was started to reach this gas, but unfortunately its progress was arrested by a series of accidents, at a depth of 3,250 feet, just as the first indications of gas were reached. He located a number of shallow

wells for shale gas in and about Cleveland, which produce about as expected.

Mr. Latimer was often laughed at for his operations with the divining rod, but he always took the banter good-naturedly, and usually laughed himself. At the same time, he believed most sincerely in the reality of the method, and in the practical value of the divining rod for prospecting purposes. He never claimed infallibility, however, knowing that the human judgment is as likely to err in this as in any other direction of inquiry; yet his successes greatly outnumbered his failures, and were in many instances truly remarkable. Some years ago he published a book on this subject, which possesses considerable interest.

For many years, Mr. Latimer used this peculiar gift very sparingly, and then not for pay. He had conscientious scruples in regard to using such a mysterious faculty for personal gain, but when at length he found himself in need of funds to carry on an enterprise to which he felt himself to have been Providentially called, he no longer hesitated to use the divining rod whenever occasion offered, and for compensation, in order that he might apply the proceeds to the undertaking which lay so near his heart.

About ten years ago Mr. Latimer read with great interest the works of Prof. C. Piazzzi Smyth, Astronomer Royal for Scotland, describing his explorations at the great pyramid of Gizeh and the remarkable conclusions he reached regarding the interpretation to be given to the structure in all its dimensions when measured in inches. Mr. Latimer was at once fascinated with the beautiful demonstrations in mathematics which the study of the pyramid afforded, and from being an earnest disciple he soon advanced to be the foremost leader and champion of the theory of the ancient origin of the British inch, of its sacred character as a divine gift to man, and of its Providential preservation from the earliest ages in the imperishable stones of the great pyramid—a structure which, ever since its construction, has challenged the attention of mankind as the greatest wonder of the world.

His own researches in regard to the pyramid were remarkable for their ingenuity and originality, and well illustrate the genius of the man. Starting with the conclusions of Professor Smyth, he carried the subject to much greater length, and made many new and valuable discoveries in the mathematical relation of the chambers of the great pyramid to the properties of the circle as interpreted by the British inch. As his conviction of the divine origin of the inch grew upon him, his intolerance of its modern competitor, the French metre, increased, and he became a most uncompromising opponent of any movement looking to the introduction and adoption of the metre as a standard in the United States. In order the more effectively to resist the progress of the meter he organized a society for preserving our ancient standards of weight and measure. This was at first composed of his personal friends, but under the magic influence of its founder, the society soon gained adherents far and wide. The novel interest in pyramid study lent its aid, and the membership spread to all quarters of the globe, including in the number some of the best scholars of our day. The society becoming thus cosmopolitan took on the name of Internacional Institute, and began the

publication of a magazine known as the International Standard, which is now in its fifth year.

As President of the International Institute Mr. Latimer's labors were greatly increased. His correspondence was very large, letters being constantly received relating to the pyramid and kindred subjects from members and friends of the cause residing in all parts of the world. It was noteworthy how soon a correspondence with him, at first merely official or technical, ripened into one of sincere friendship and cordiality. He was the life and the inspiration of the Institute, the members at home and abroad clustered around him in sympathy as honey bees around their queen. It was largely his enthusiasm that gave the Institute vitality, and his magnetism that gave it coherence. Now that he is gone it is at a loss for a leader to fill his place.

His value to ourselves as a member of the Civil Engineers' Club is too well understood to need description from me. His social qualities made him ever a centre of attraction, his amiability endeared him to every one, while his large attainments and experience as a civil engineer won for him universal admiration and respect. The year during which he served as our President was unprecedented in the history of the Club for the frequency of the meetings, the largeness of the attendance and the number of professional papers read and discussed. His own contributions to our Transactions at various times were highly appreciated. He took a deep interest in the movement looking to the reorganization of our national public works, and lent his influence in favor of the Council of Civil Engineering Societies now engaged in promoting this most important reform.

As a citizen, Mr. Latimer was invariably found on the right side of every moral question. He was in favor of all true reform in society and in the State. He sympathized with and actively aided the humane and charitable institutions of our city. He mingled freely and cordially with men of all ranks and classes, and himself set a lofty example of all that a true citizen of our free Republic ought to be.

Mr. Latimer had a deeply religious nature. Both by early training at his pious mother's side and from the deep convictions of his own soul, he lived in an atmosphere of spirituality which kept him separate from the evil that is in the world. He was remarkably free from the bigotry of sect, from the sanctimony of the Pharisee and the narrowness of the uninformed. Although he never introduced the subject of religion amid secular affairs, yet every one knew him as a pious man and felt in some measure the influence of his genuine religion. He was a bright illustration of the divine precept, "by their fruits ye shall know them." His whole life being governed by religious principle was serene and clear and radiant with the lustre of Christian character.

" Wise, steadfast in the strength of God, and true,
The kindly, earnest, brave, far-seeing man,
Sagacious, earnest, dreading *praise* not *blame*."

He was a faithful attendant upon the church of his choice. He labored diligently for the Master in the Sunday school, and, in addition to this, he gathered about him a large class of young Chinamen, whom

he regularly instructed on Sunday afternoons in the rudiments of our language and in the blessed truths of the Gospel of Christ. That he also won their hearts need not be said; and there was, perhaps, no more touching tribute to his memory than the attendance in a body of these dusky sons of the Flowery Land at his funeral services, as they laid their floral offerings in mute sorrow upon his bier.

Thus we see that Mr. Latimer was a many-sided man. The interests with which he was connected seemed to multiply with his years, and in his heroic efforts to give to each the attention that it seemed to demand, we may find perhaps the secret of his untimely death. An indefatigable worker, his life was one of ceaseless activity. In all his hours of labor his mind was intently occupied, and his strength was taxed to the utmost. Of late years he took no vacation whatever; he seemed to have no time for play. Perhaps he relied too much on the strength of his constitution, but as the bow too long and severely bent will break at last, so he succumbed in a moment to the fatal stroke. In the strength of his manhood, in the midst of his activities, and with many a noble ambition yet unfulfilled, he was suddenly cut off, like a hero in the thick of the battle.

As by the gentleness of his life all hearts were won to him, so by the suddenness of his death were all hearts deeply touched and saddened. Though his modesty prevented him from a career of large worldly success and renown, such as would have made Wealth pay tribute to his greatness, and Fame build temples to his memory, yet in his own way he lived a noble life, building up a character untarnished by any mean or selfish act, setting an example of goodness and virtue too rarely found in our midst, and leaving behind him a host of sorrowing friends who can but bewail their loss while striving to emulate his splendid virtues.

“Peace, peace! he is not dead, he doth not sleep,
He hath awakened from the dream of life.
’Tis we, who lost in stormy visions, keep
With phantoms an unprofitable strife.
He has outsoared the shadow of our night,
And that unrest which men miscall delight.”

AN INVESTIGATION AS TO HOW TO TEST THE STRENGTH OF CEMENTS.*

BY JEROME SONDERICKER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read January 18, 1888.]

Within the past year there have been designed in the Laboratory of Applied Mechanics of the Massachusetts Institute of Technology, apparatus for testing the compressive and tensile strength of cement which are believed to possess some valuable features; a description of the

* This paper was also read at the November, 1887, meeting of the American Society of Mechanical Engineers.

apparatus and some of the results obtained from them will be presented in this paper.

COMPRESSION APPARATUS.

The compression apparatus was designed for testing not only cement, but also stone, iron, and other materials of construction. It was made to be used with an Olsen 50,000-pound testing machine. A side view of it is shown in Fig. 1. The two pieces of steel, *A* and *B*, are fitted to the slot in the middle of the movable cross-head of the machine, and are bolted together by two $\frac{1}{2}$ -inch bolts. These pieces receive the upper compression plate *D*, which is secured to them by means of the centre bolt, one inch in diameter. This plate is five inches in diameter. It is provided with a spherical bearing of two and one-half inches radius, the centre of the spherical surface being at the centre of the lower surface of the plate. The washer *C* is also provided with a spherical bearing surface concentric with the other, in

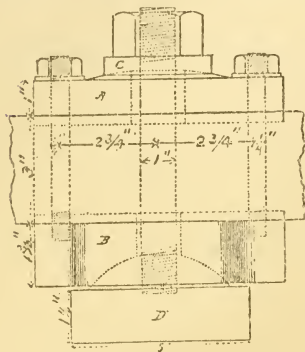


Fig. 1.

order that it may have a firm seat in any position of the plate. The lower compression-plate is a cylinder one and one-half inches thick and five inches in diameter. It is doweled to the platform of the machine, its centre being exactly under the centre of the upper plate. Concentric circles are described on its upper surface, to admit of centering the specimen to be tested. Both plates are made of steel, their working surfaces being hardened and ground plane.

Two requisites of apparatus for testing the compressive strength of specimens provided with plane bearing surfaces are as follows :

- 1st. When adjusted in position, the plates shall bear uniformly over the whole surface of the specimen.
- 2d. During the progress of the test, the moving plate shall remain parallel to its first position.

These conditions were designed to be satisfied, as nearly as possible, in the apparatus just described by the following means :

1st. By providing the spherical bearing so as to make the upper plate adjustable.

2d. By making the radius of this bearing sufficiently large, so that the friction due to the pressure exerted, aided, if necessary, by tightening the nut of the centre bolt, would be sufficient to prevent slipping from taking place, due to any eccentric pressure ; such as would occur, for example, in the testing of a long iron specimen as a result of its side deflection when near the point of rupture.

In order to secure a uniform bearing over the surface of the specimen, the plate is suspended loosely in its socket ; then, the specimen having been placed in position on the lower plate, the upper plate is brought down upon it slowly, at the same time being adjusted by hand approximately parallel to the surface of the specimen. As soon as the plate

comes in contact with the specimen, it tips about its centre until it comes to an even bearing.

In order to determine whether the friction of this spherical bearing would be sufficient to prevent slipping in ordinary testing operations in case the pressure should become eccentric, a wrought-iron specimen, five inches long and one inch in diameter, was tested. At intervals during the progress of the test, the distances between four points 90 degrees apart, near the outer edges of the plates, were calipered with a micrometer caliper reading by graduation to thousandths of an inch, and by estimation to ten thousandths. By this means no slipping could be detected, even after the pressure had become eccentric to the amount of one-eighth of an inch, due to the side deflection of the specimen. This would correspond to a frictional resistance in the bearing of about .04 of the normal pressure. A second experiment was made to determine the amount of eccentricity which would just produce slipping in the joint when not oiled. A cylinder of iron, one inch in diameter, was submitted to pressure on its curved surface, and the eccentricity necessary to produce slipping under various loads was noted. The test was performed as follows: The plate was clamped in position, sufficiently firmly to prevent slipping under the eccentric load, by tightening the nut on the centre bolt. The specimen was then placed eccentrically in the machine, and subjected to various pressures up to 10,000 pounds. After applying the pressure the nut was loosened, thus allowing the friction of the ball joint to act alone in resisting the moment of the eccentric load. It was found by this means that, for all the loads tried, the plate began to slip when the eccentricity amounted to three-eighths of an inch. This would correspond to a coefficient of friction in the joint of about .12. No use has been made thus far of the centre bolt, except for suspending the plate, and for this purpose, of course, it might have been made much smaller, together with the plate A. It is desirable, however, to have some means for fixing the plates parallel to each other, and also for providing for extremely eccentric pressures; the centre bolt answers these purposes. It will be noticed that as the centre of the spherical joint is in the centre of the lower face of the plate, this point remains stationary in all positions of the plate, so that the pressure upon it is central however it may be inclined; also, the minimum amount of sliding between the plate and specimen occurs as the plate is coming to a bearing.

In testing a cube of cement, two opposite surfaces are rubbed down with water on a piece of slate, in order to remove any small surface irregularities. The load is at first applied rapidly up to a point well within the breaking load, and then slowly, and at a uniform rate of speed till fracture takes place. In order to ascertain the degree of uniformity of results to be obtained in the use of this apparatus, a number of tests have been made of two-inch cubes of both Portland and Rosendale cement, with and without sand, and from one week to three months old. Four cubes were made at one mixing, and all tested at the same time. Table I. gives the results of these tests, including the mean breaking load for each set of four specimens, the maximum variation of any one test from the mean, and the extreme variation occurring in each set.

It will be noticed that the variations are quite small, the average maximum variation from the mean being 1.9 per cent., and the average extreme variation 3.0 per cent. No extraordinary precautions were employed in making these tests; they are believed to represent what may be expected in the ordinary use of the apparatus.

TENSION APPARATUS.

It is a well-known fact that the means commonly employed in determining the tensile strength of cement give results varying within wide limits, variations of 20 per cent., and even 30 per cent. in the strength of specimens of neat Portland cement from the same mixing being quite common, and this in the hands of careful experimenters. An examination of the report of Maclay's experiments, published in the Transactions of the American Society of Civil Engineers for 1877, shows extreme variations in the sets of five specimens of neat Portland cement, having a sectional area of $2\frac{1}{4}$ square inches, as high as 35 per cent., differences of 20 per cent. and more occurring frequently. These wide variations are assignable partly to the impossibility of mixing the mortar and filling the molds so as to obtain briquettes of exactly the same strength, and partly to inexact methods of testing.

Experiments have been made in the laboratory with the view of reducing that portion of these variations resulting from the methods of testing employed. For this purpose clips have been designed, which are intended to eliminate eccentric pulls in applying the load.

Before giving a description of these clips, a few explanations will be made. The form of briquette in use in the laboratory is that shown in Fig. 2. The outline of the neck and bearing surfaces consists of circular arcs of one inch radius, terminated by straight lines tangent to them, and having a slope of 1 to 2 with the

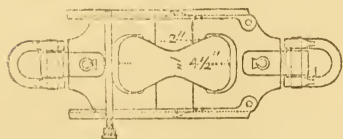


Fig. 2.

axis of the briquette. The sectional area at the neck is one square inch. The clips first in use had flat bearing surfaces having the same slope as the sides of the briquette. They came in contact with nearly the whole of the flat portion of the sides of the specimen, leaving a free space of about one inch between their points. Upon trial, it was found that quite a large percentage of fractures occurred at the edge of the clips. The following experiment was then made: Four narrow, thin strips of steel were inserted between the clips and briquette, so that the briquette bore upon these strips instead of upon the surface of the clips. It was found that as the strips were moved farther away from the neck of the specimen, the number of fractures occurring outside of the smallest section diminished, and at the same time the breaking strength increased, until, when the strips were placed two inches apart, nearly all the fractures occurred at the smallest section. Two inches was therefore selected for the distance between the bearing points of the clips for this form of briquette. The clips shown in Fig. 2 were then designed.

Two guides, grooved to a depth of $\frac{1}{8}$ inch, are hinged to the upper clip.

The lower clip is secured in the guides by means of the clamp-screw *A*; the springs *B*, attached to the upper clip, release the lower clip from the guides when they are unclamped. A central pull is secured by means of two pairs of knife-edges at right angles to each other, the outer pair being inserted in the yokes which bear on the inner ones. The yokes are prevented from moving sideways by means of projecting points bearing against the sides of the clips. The bearings of the yokes on the inner pair of knife edges are notched, as shown in the figure; thus the yokes occupy a definite position. The outer knife-edges are adjusted so that their plane passes exactly through the axis of the clips, as are also the inner ones; thus the line of pull, which is determined by the intersection of the planes of the two pairs of knife edges, is made to pass through the axis of the clips when these are clamped. The bearing surfaces of the clips upon the briquettes are rounded, forming blunt points.

These rounded bearing surfaces must be made accurately, and used intelligently, in order to secure reliable results. The points must be exactly central, and the bearing surfaces of the briquette square with its face; even then the adjustment of the specimen in the clips by hand in the ordinary manner can only secure an approximately central pull, varying with the degree of care exercised by the operator and the condition of the bearing surfaces of the briquette. The object designed to be attained by the clips just described, is to secure a definitely central pull, at the same time making the task of adjusting the specimen in the clips as simple as possible. The operation of testing is as follows:

In order to prevent the lower clip from dropping when the specimen breaks, a loosely-fitting brass band is slipped over the briquette before it is placed in the clips. The lower clip is raised sufficiently to allow the specimen to be placed in position, and clamped firmly enough to support its own weight. The specimen is inserted, and the lower clip drawn down till the bearing surfaces of the briquette are just in contact with it. The briquette is then adjusted so that its faces are flush with the faces of the clips. A load, usually about one-half the breaking load, is rapidly applied. This forces the blunt points of the clips into the specimen, thus obtaining a firm bearing before the guides are removed. The guides are unclamped, the springs freeing them from contact with the lower clip. The stress is then applied slowly and at a uniform rate till fracture takes place. Before taking out the fractured specimen, the lower clip is clamped in position ready for another test. The only hand adjustment is in placing the specimen flush with the faces of the clips. The only possible eccentricity will be caused by the imbedded points not acting at the centre of the specimen; if the points are themselves central and the sides of the briquette square, this will not occur. If, however, it does, it can be detected by the clips springing to one side when the guides are unclamped. The grooves in the guides of the experimental apparatus are unnecessarily deep. With shallower grooves, admitting of more rapid clamping and unclamping of the guides, it is believed that the operation of testing may be performed fully as rapidly as by the usual method. The adjustment of the specimen in position is so simple a matter that the clips may be used by any careful workman

with a certainty of securing reliable results. The knife-edge bearings answer the same purpose that is claimed for conical points, and are less liable to be dulled by use with heavy loads.

In order to determine the degree of uniformity in the results obtained by the use of this apparatus, 117 specimens have been tested. They include both Portland and Rosendale cement, with and without sand, and from seven to twenty-eight days old. The briquettes were made in sets of four, four molds being filled from one mixing. Three sets of specimens were made at the same time from three different mixings, using the same ingredients in all, and attempting to obtain the same quality of mortar. Table II. gives the results of these tests, including the mean strength of each set of briquettes, the maximum variation from this mean in pounds and per cents., and the extreme variation occurring in each set in pounds and per cents. The three sets of specimens made the same day with the same ingredients are grouped together and marked *a*, *b* and *c*. Four of the specimens tested are excluded from the table; these are reported in the column of remarks, with the reasons for their exclusion. It will be seen from this table that the maximum variation from the mean is included between 0.6 per cent. and 16.3 per cent., with an average of 5.7 per cent. The extreme variation in strength in each set is from 1.2 per cent. to 25.6 per cent, with an average of 9.7 per cent. The cement in each case was unsifted, and the sand, ordinary coarse sand, sifted but not washed. The mixture was in each case of about the consistency of ordinary mortar, 25 per cent. of water being used with the neat Portland, and 37½ per cent. with the neat Rosendale cement. It is believed that these results represent what may be expected in ordinary testing operations by the use of the clips described.

EFFECT OF AN ECCENTRIC LOAD.

In order to determine the effect of a slightly eccentric pull, the experiments recorded in Table III. were made. Briquettes of the same mixing are grouped together. In the sixth test the briquette showed a large cavity near one edge of the fractured section. This, doubtless, decreased its strength considerably. The effect of such a cavity cannot be estimated wholly by the area it occupies, as it also causes a non-uniform stress at the section. Briquette No. 8 was first subjected to a central stress of 640 pounds without fracture. It was then replaced in the clips $\frac{1}{16}$ inch out of the centre, and broke at 528 pounds, as recorded in the table. Omitting the second group, this experiment shows a decrease in strength due to a pull $\frac{1}{16}$ inch out of the axis of the briquette of 12 per cent. for the first group, 17 per cent. for the third and fourth and 10 per cent. and 9 per cent. for the fifth and sixth groups respectively. The ordinary formula for eccentric loads would give a decrease of strength of 27 per cent. A greater number of tests would be necessary to determine the exact percentage of decrease of strength due to a slight eccentricity, but these serve to show the importance of guarding against eccentric stresses in cement testing, however slight they may be.

The machine used in making all the tensile tests was a single lever suspended in a wooden frame, the loads applied being indicated by a

spring balance. This machine was tested at the conclusion of these experiments, and found to be correct.

The form of briquette used in making these tests is somewhat more slender at the neck, and considerably longer than that recommended by

TABLE I.
COMPRESSION TESTS OF 2-INCH CUBES.

CEMENT.	Age.	Breaking load on 4 sq. in. Mean of 4 specs.	Max. variation from mean.		Extreme variation.		Remarks.
			Lbs.	P. c.	Lbs.	P. c.	
Portland, neat.	95 d.	22,540	440	2.0	742	3.3	
" "	88 d.	18,981	181	1.0	270	1.4	
" "	77 d.	15,982	82	0.5	145	0.9	
" "	9 d. 6 h.	9,534	69	0.7	122	1.3	
" "	9 d. 1 h.	9,473	97	1.0	179	1.9	
" "	28 d.	21,616	101	0.5	180	0.9	
" "	14 d. 5 h.	17,867	242	1.3	375	2.1	
" "	13 d. 20 h.	16,469	269	1.6	450	2.7	
" "	7 d. 1 h.	10,061	164	1.6	225	2.2	
" 3 pts. sand.	14 d.	2,269	54	2.4	92	4.0	
Rosendale, neat.	76 d.	9,226	159	1.7	255	2.8	
" "	24 d.	4,210	310	7.4	470	11.1	
" 1 pt. sand.	14 d.	1,429	37	2.6	70	5.0	
Mean.....			19		3.0		

TABLE III.
EFFECT OF AN ECCENTRIC LOAD.

CEMENT.	No. of test.	Age.	Breaking load.	REMARKS.
Portland, neat.....	1	107 d.	508	Stress central.
	2	107 d.	516	Stress central.
	3	107 d.	444	Stress $\frac{1}{16}$ inch eccentric.
	4	107 d.	450	Stress $\frac{1}{16}$ inch eccentric.
Portland, neat	5	23 d.	596	Stress central.
	6	23 d.	372*	Stress $\frac{1}{16}$ inch eccentric.
Portland, neat	7	23 d.	632	Stress central.
	8	23 d.	528†	Stress $\frac{1}{16}$ inch eccentric.
Rosendale, neat.....	9	24 d.	130	Stress central.
Portland, neat.....	10	24 d.	108	Stress $\frac{1}{16}$ inch eccentric.
	11	12 d.	423	Stress central.
Means of 6 specimens ...	12	12 d.	379	Stress $\frac{1}{16}$ inch eccentric.
Rosendale neat.....	13	11 d.	86	Stress central.
Means of 6 specimens....	14	11 d.	78	Stress $\frac{1}{16}$ inch eccentric.

* Broke in a large cavity near edge of fractured section.

† Subjected to a central stress of 640 pounds. This was then removed and the eccentric stress applied.

the Committee on Cement Testing of the American Society of Civil Engineers. No comparative tests have been made to determine the relative value of the two forms. There are two qualities developed by testing which a cement briquette should possess. 1. The fracture should

TABLE II.

TENSION TESTS.

Briquettes 1 square inch section.

CEMENT.	Age.	Breaking load Mean of 4 specs.....	Max. varia tion from mean.		Extreme variation.		Remarks.
			Lbs.	P. c.	Lbs.	P. c.	
Portland, neat.	28 d.	(a) 616	28	4.5	52	8.4	Mean of 3 specs. 4th broke in large cavity at 492 lbs. Mean of 3 specs. 4th broke in large cavity at 558 lbs.
" "	28 d.	(b) 651	15	2.3	24	3.7	
" "	28 d.	(c) 620	26	4.2	50	8.0	
" "	14 d.	(a) 490	34	7.0	60	12.3	
" "	14 d.	(b) 523	55	10.5	82	15.7	Mean of 3 specs. 4th placed ec- centrically in clips and broke at 482 lbs.
" "	14 d.	(c) 521	19	3.6	36	6.9	
" "	13 d. 19 h.	(a) 573	27	4.7	54	9.4	
" "	13 d. 19 h.	(b) 561	35	6.2	58	10.3	
" "	13 d. 19 h.	(c) 550	26	4.7	46	8.4	Mean of 3 specs. 4th subjected to eccentric load and broke at 228 lbs.
" "	7 d.	(a) 322	8	2.5	13	4.0	
" "	7 d.	(b) 324	3	0.9	4	1.2	
" "	7 d.	(c) 312	2	0.6	4	1.3	
" 3 pts. sand.	14 d.	(a) 89	7	7.9	12	13.5	Mean of 3 specs. 4th broke in taking out of mold. Mean of 3 specs. 4th broke in taking out of mold.
" "	14 d.	(b) 90	7	7.8	12	13.3	
" "	14 d.	(c) 86	14	16.3	22	25.6	
Rosendale, neat.	24 d.	(a) 176	8	4.5	14	8.0	
" "	24 d.	(b) 170	10	5.9	20	11.8	Mean of 3 specs. 4th broke acci- dentally.
" "	24 d.	(c) 176	5	2.8	8	4.5	
" "	14 d. 4 h.	(a) 94	8	8.5	12	12.7	
" "	14 d. 4 h.	(b) 97	2	2.0	5	3.1	
" "	14 d. 4 h.	(c) 88	8	9.1	12	13.6	Mean of 3 specs. 4th broke acci- dentally.
" "	13 d. 19 h.	(a) 76	2	4.0	5	6.6	
" "	13 d. 19 h.	(b) 84	5	6.0	9	10.7	
" "	13 d. 19 h.	(c) 88	6	6.8	10	11.4	
" "	9 d.	(a) 82	2	2.5	4	5.0	Mean of 3 specs. 4th broke in taking out of mold.
" "	9 d.	(b) 67	3	4.5	6	9.0	
" "	9 d.	(c) 67	5	7.5	10	15.0	
" 1 pt. sand.	14 d.	(a) 60	4	6.7	7	11.7	
" "	14 d.	(b) 59	4	6.7	7	11.7	Mean of 3 specs. 4th broke in taking out of mold.
" "	14 d.	(c) 57	5	8.8	8	14.0	
Mean			5.7		9.7		

take place at the smallest section. 2. The breaking strength should be the maximum obtainable, the mortar being of ordinary stiffness. The latter requisite can only be determined definitely by comparative tests of different forms of briquette. In the tests just described, out of the 117 specimens tested, 88 specimens, or 75 per cent., broke at or within $\frac{1}{8}$ inch of the smallest section; 20 specimens, or 17 per cent., at a distance of about $\frac{1}{4}$ inch; 5 specimens, or $4\frac{1}{2}$ per cent., at about $\frac{3}{8}$ inch; 4 specimens, or $3\frac{1}{2}$ per cent., at about $\frac{1}{2}$ inch distance from this section. The areas of the cross sections of the briquettes at these points are, at $\frac{1}{8}$ inch, 1.01 square inches; at $\frac{1}{4}$ inch, 1.06 square inches; at $\frac{3}{8}$ inch, 1.15 square inches, and at $\frac{1}{2}$ inch, 1.26 square inches. None of the specimens broke within $\frac{1}{2}$ inch of the bearing points of the clips. Further investigation will be made in this direction.

DISCUSSION.

Mr. Phineas Ball: In my experience in testing cements a want has been felt of some more satisfactory method of applying the strain or force in finding the tensile strength of cement than by the ordinary clamp. The most satisfactory form of the usual make has been found to be the one with the circular end, approaching somewhat those proposed by Mr. Sondericker. The one proposed and experimented with seems to be a genuine improvement, and one calculated to advance the science of testing cements. It is a matter of congratulation that Mr. Sondericker has been able to put in practice with such good results his improved device. It is to be hoped that the device may prove as useful and efficient in the hands of other experimenters as in his.

As to the cause of the irregularity appearing in the result obtained from samples of the same mixture and treatment, my observations have led to three conclusions:

First. Unequal filling of the molds. A slight variation in compressing the mortar into the mold will make a marked change in the result.

Second. To a slight disturbance of the sample on being removed from the mold.

This operation is very important, to so manage it as to cause the least possible shock to the sample in its green state. To interfere by a violent disturbance of the sample, as by a sudden jar, however seemingly gentle, when the setting has proceeded only one or two hours, is to alter the final result obtained in 24 hours, one week or one month, materially. Care in this operation is all important that the handling as well as the filling of the mold should be uniform in all its course from the removal from the mold to its final resting place, where it shall complete its hardening.

Third. Uniformity of after treatment on being removed from the mold.

The temperature to which it is subjected should be as uniform as possible, and for all of the series.

It is well known that cement hardens very slowly in the air or in water below a temperature of 50 degrees Fahr. The setting mass appears to lie inert, lifeless. About 70 degrees appears to be the best point for active efficient consolidating; and between these extremes the operation of hardening varies somewhat as the temperature. And hence if for

any reason, or from some slight change in position, among the several samples one gets more warmth than another, when all come to a test the variation will appear. If samples are indurated in the air, it should be done away from the sun's rays and where there is much moisture in the atmosphere. If in water, it should be done in the shade and at a uniform temperature to insure uniform results.

In testing about eleven hundred barrels of cement for concrete work in a dam, all samples were buried in moist sand about two inches deep and in the shade. The testing was done in July, August and September.

This method gave low results for seven days, but quite excellent results in thirty days. The object was to test the cement in conditions nearly like those in which the cement would be placed when put in the work, as the material of which the dam was to be made was all sand and gravel on either side of the core wall. The results obtained by this course were on the whole quite satisfactory in all respects. Variations appeared, but no larger or more divergent than by other modes of treatment.

Mr. Eliot C. Clarke: In making these experiments, did you note the temperature of the water used for mixing the mortars, or of that in which they were immersed, or of the air in the mixing room?

Mr. Sondericker: The temperature of the water with which the cement was mixed varied from 65 to 75 degrees Fahr. The temperature of the water in which the specimens were immersed was the same as that of the laboratory, which averages about 70 degrees Fahr.

Mr. Clarke: The tests seem to have been made with great fairness, and it is satisfactory to see that all of the specimens broke under stresses which varied so little from the average. In testing cement for the Main Drainage Works, Boston, we found, as a rule, that about eight out of ten briquettes would break under nearly uniform loads; but that the other two would vary greatly from the average. I supposed that this was due to occasional eccentricity of pull in our machine.

Mr. F. L. Fuller: I would like to ask if the weights of these different briquettes were taken.

Mr. Sondericker: The weights of some of the cubes were taken, and the variation in weight for any one set of specimens found to be very slight.

Mr. Clarke: I hope that Mr. Sondericker will find time to make a series of tests in which variations of temperature in the air and water will be factors. I suspect that the influence of moderate differences of temperature has been overrated. It would be well to know the truth about it, because in actual practice an engineer has little time to devote to noting unimportant differences in condition.

Mr. F. P. Stearns: I remember that many cement tests were made during the construction of the Sudbury Aqueduct, in a room that was not heated. In the cooler weather of the spring and autumn the briquettes of neat Rosendale cement would set very slowly for an hour or two, as indicated by the wire test, but at the end of 24 hours their tensile strength was the same as in the warmer weather.

Prof. Lanza: I should like to ask Mr. Clarke how much reason there

really is for determining the strength of cement by a tensile rather than by a compressive test.

Mr. Clarke : I prefer the tensile test, and my reason is that when masonry actually fails, it commonly is because the mortar joints are ruptured by tensile stress. Perhaps I can explain this at the blackboard.

Let this sketch represent an arch and its abutment. If such an arch is overloaded it settles at the crown and bulges at the haunches, as shown in an exaggerated way by the sketch. As distortion takes place the masonry at *A* is subject to tension below and to compression above ; at *B* the position of these strains is reversed. Since mortar yields more readily to tension than to compression, failure takes place by tearing apart of the joints, as indicated. So in sliding, as at *C*, or in overturning, as at *D*, the mortar is first torn apart. Probably the compressive strengths of most cements correspond with their tensile strengths ; but as mortar commonly fails by lack of tensile strength it is this which should be tested.

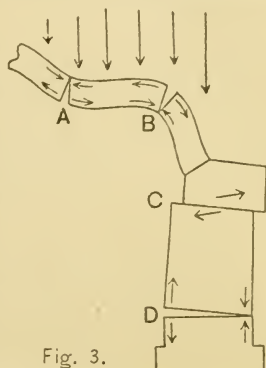


Fig. 3.

President Rice : Mr. Clarke's suggestion about observing the temperature of the water in which the cement was mixed brings to my mind some statements made in this country and abroad in relation to the freezing of cement. When I first began work it was generally accepted that frost was a thing to be excluded from cement work of any kind ; that it was fatal to it. It is now advanced by some that it is not fatal to it, but an improvement. I would like to ask whether any gentleman present can give us any information on this subject.

Mr. Clarke : I often have seen cement mortars that were injured by frost. I think strong Portland cement mortars, as a rule, withstand freezing.

President Rice : A gentleman made a statement to me that he put up a wall in "half cement mortar" (so far as my experience goes that means mortar made of lime, with a cement barrel standing near by). The wall was built, but the ground was frozen, and in the part near the ground the tenacity of the mortar was destroyed and it could be picked out for several inches; but it was allowed to stand all winter, and when warmer weather came again it was found that it had frozen and thawed, and then setting took place and it was in as good condition as if it never had been frozen. I never heard but one person make such a statement.

Mr. Stearns : The kind of masonry laid in freezing weather is an important element. With brick masonry, the bricks, being porous, absorb the surplus water from the mortar, making it set sooner, and at the same time less liable to disintegration by the particles of water when they expand into ice. I would put concrete at the other extreme as a kind of masonry that sets slowly and has the greatest amount of water mixed with it mechanically. Masonry at a level with the surface of moist ground is in a much less favorable position as regards freezing than that

above the ground. I recall one instance where concrete made with Rosendale cement was laid in moist ground, level with the surface, late in the autumn. It was then covered with a thin layer of gravel. The next spring the concrete was worthless, showing no signs of setting after being uncovered for several weeks. The cement used was of good quality.

Mr. Clarke : Have you not seen brick masonry that was injured by frost ?

Mr. Stearns : I have seen bricks loosened for a half dozen courses down from the top of a wall ; and I have seen a scale of mortar thrown off from joints on the inside of an arch. This same arch was taken down in the spring and the mortar which had been frozen was good and adhered firmly to the bricks. My experience in these matters is wholly with work done late in the autumn and not in the severe cold weather of winter.

Mr. Clarke : I once made a large number of sample blocks of concrete. Some of them were made with Rosendale cement and some with Portland cement. All of them were buried in the ground for eight months. At the end of that time, when dug up, they all seemed solid and hard. Then they were left on the surface of the ground, exposed to the weather, for several years. All those made with Rosendale cement disintegrated in time, while of those made with Portland cement only one specimen was affected by the weather, and that one was made with mortar which contained but one part of cement to six parts of sand.

President Rice : Does the experience of any of those present cover sewer pipe made of cement, whether the frost has effect on that or not.

Mr. Clarke : The large sizes used for well curbing must stand frost, or they would not answer their purpose. Probably they are made with a large proportion of Portland cement.

President Rice : I remember a wall on the road to Cambridge, about half way between Harvard College and Mt. Auburn, made that way, and it was apparently good.

Mr. Sydney Smith : I remember seeing the foundations of several wooden houses made of cement blocks that the frost or something else had pretty badly used up. These cement blocks were used between the wooden structure and the stone foundation. There were cracks all through the cement work, and the blocks had scaled off as if it had been done by frost.

President Rice : I remember a sidewalk made of dry-pressed brick, and the next spring after they were laid down you could scrape an inch of dust off the middle. It had to be renewed the next spring. That was probably due to water getting into the crevices of the brick in consequence of being made of dry clay.

Mr. C. F. Allen : In relation to the effect of frost upon cement or concrete, it seems to me that something might be learned from the work of Dr. Goodridge in repairing arches with concrete. In many cases the work extends below the water and the concrete must be kept wet several inches above the water line. It is claimed that there have been no failures. This would indicate that there are some cements at any rate that are not affected by frost under extremely trying circumstances.

There were experiments made in Providence some years ago that indicated that a mixture of fine and coarse sands gave better results than either the fine or coarse sand separately. I simply remember that such results were obtained. I do not remember how many specimens were broken nor any of the details, and do not remember whether the tests were carried far enough to settle anything definitely. I prefer to consider the result as an indication simply and mention it as a good point for experiment.

Mr. Clarke: Experiments on that point made for the Main Drainage Works indicated that mortars made with coarse sand are the strongest and that the strength decreases in proportion as the particles of sand used are smaller. But mixed sand, made of particles of all sizes, from fine to coarse, gave nearly as high results as coarse sand.

Mr. Allen: The fine sand used, as I remember it, was a very fine, but clean and sharp sand. At the last convention of the American Society of Civil Engineers, there was cited a case of thoroughly good cement which was first mixed with a fine sand and gave very unsatisfactory results. There was no good coarse sand reasonably accessible, and it was a matter of some little expense to procure coarse sand. It occurred to me that in such cases it would have a definite value commercially to be able to use a mixture of coarse and fine sands if equally strong in such a case as that.

President Rice: I think that is one of the dangers that you would meet in actual practice. Any mixture is very quickly seized upon by the contractor. I remember in St. Louis they were building some sewers, and it was discovered by the contractors that the various mixtures had a "definite value" economically, and sand and cement being valuable material, they scraped up the dust in the street and made their mortar with that. It was economical for the contractors, but it did not improve the sewer any.

Mr. Sondericker: I have a suspicion that the strains developed in a cement briquette while it is setting in the mold, due to expansion and contraction, may have something to do with variations in tensile strength. I once tested a sample of Portland cement, which contracted very appreciably while setting. Some of the briquettes made of this cement cracked across the smallest section while in the molds. The crack would begin on the surface of the briquette at one side, and gradually deepen and widen until, by the time the cement was completely set, the crack would extend to half the depth of the briquette, across its whole face, and be from one hundredth to two hundredths of an inch wide. Is it not possible that strains may be produced in briquettes from a similar cause—not sufficient to rupture the specimen, but sufficient to materially weaken it?

Mr. Clarke: I never noticed briquettes cracking in the molds. If the mortar contracted would it not simply ease itself from the mould? It would not stick to the brass.

Mr. Sondericker: It might stick to the bottom sufficiently to resist the tendency to contract of the briquette while setting. A prism of the same cement, about one foot long, made without lateral support on a piece of glass, behaved in a similar manner.

Mr. Clarke: Internal strains seem to develop in mortars of neat cement a year or more old. Such mortars are very hard and brittle. When they break under a pull they frequently fly into a dozen pieces.

President Rice: That brings up the subject of the contraction of cement. It has been a long time urged that the settlement of masonry was avoided by the use of cement instead of lime mortar. That was one reason why cement work was preferable to lime work. I would like to hear some one on that subject.

Mr. Clarke: I made some rough experiments on that point. I made ten-inch cubes of different kinds of mortar, allowing some of them to harden in water and others in air. From time to time their sizes were measured by calipers. No change of size as great as .01 inch was detected. Undoubtedly there is *some* change. If cement mortar is put into a bottle to harden, it always cracks the bottle. I believe some good experiments on expansion of mortars have been made lately at the Institute of Technology.

President Rice: We know that in the case of a brick wall 50 feet high made with lime mortar, the height of that wall within six months would be from one to two inches less than when first laid. With cement mortar the shrinkage would be much less—not discoverable.

Mr. Clarke: Cement mortar seems to expand and contract greatly under the influence of heat and cold. I have an example of that in my own house. On two of my fire-places the architect placed decorative fronts made of slabs of Keene's cement, four inches thick. On building a fire in one of the fire-places the cement cracked badly.

Mr. Smith: Was there not some other material used with it, so that the crack may be accounted for by the unequal contraction or expansion of different materials?

Mr. Clarke: The fire-places were built in the usual manner, and the slabs of cement set in front of them as would be done with tiles. Perhaps some mortar was used to fasten them to the bricks.

President Rice: Could that not have been due to the settling of the woodwork.

Mr. Clarke: Possibly it was; but the cracking occurred when the first fire was lighted, and in the case of the other fire-place, where there has been no fire, the cement has not cracked.

Mr. Stearns: The bottom of the Moon Island Reservoir is made of concrete. Each division of the reservoir is 300 or 400 feet long by 150 feet wide. The concrete has cracked in places, and I have always attributed it to contraction due to cold weather, though it may possibly have been caused by shrinkage of the masonry.

Mr. H. D. Woods: The Vanne aqueduct through the forest of Fontainebleau has been found to crack by expansion and contraction. The conduit is 2 m. diameter in the clear. Some 6 kilom. of the aqueduct through the forest is built of Coignet beton arches, which are exposed to the sun. It has been found that a crack appears along the whole top of the conduit longitudinally, which opens at noon and closes at night, also slight cracks laterally just above the water line (where the concrete is not cooled by the contact of the flowing water). In the large span arches, 30 m. and 35 m., the arch has been found to rise during the heat

of the day, and cause cracks in the invert of the conduit. There is but 0.80 or 0.90 m. between the intrados of these large arches and the invert of the conduit. Longitudinal expansion and contraction causes cracks crosswise of the conduit above water line, at about even distances, so that in continuing the work the conduit was sawed through every 4 m. in length, and a lead expansion joint inserted to take up this motion and prevent any leakage of water from the inside. The thickness of the conduit is 0.21 m. at the top, and 0.50 m. on the horizontal diameter; at the bottom or invert, it varies with the span of the arches below, 0.30 m. for 7 m. span, 0.40 m. for 12 m., 0.80 for 30 m., and 0.90 m. for 35 m. span, which occurs but once or twice. Cracks have also appeared at different times in the concrete of the Mont-souris reservoir, supposed to be due to expansion. In this case about 6 inches of the surface is removed, the crack grouted in cement, then a sheet of rubber is placed over it with liquid rubber cement, and the rest filled up with beton well rammed.

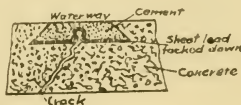


Fig. 4.

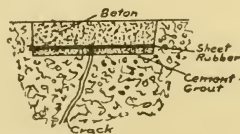


Fig. 5.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 16, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, at 7.30 P. M., President FitzGerald in the chair, 59 Members and 17 visitors present.

The record of the last meeting was read and approved.

Messrs. Edgar S. Dorr and Edmund B. Weston were elected Members of the Society.

The following were proposed for membership: Richard Fobes, of Worcester, recommended by L. A. Taylor and Dexter Brackett; Charles E. Houghton, of Boston, recommended by E. W. Howe and C. E. Putnam; Robert H. Richards, of Jamaica Plain, recommended by Dwight Porter and G. F. Swain; Henry B. Wool, of Woburn, recommended by H. H. Carter and C. W. Folsom.

On motion of Mr. Brooks, the Committee on Weights and Measures were authorized, if in their judgment it is advisable, to add to their report, now in press, a brief mention of the recent enactment of the United States Congress, proposing a conference of American nations.

The Treasurer, Mr. Manley, reported that the Committee appointed at the last meeting to invest a portion of the Permanent Fund of the Society had attended to that duty, and had purchased nine shares of the Chicago, Burlington & Quincy R. R. stock.

Mr. William E. McClintock read a paper entitled "Construction and Ventilation of Small Pipe Sewers," and Mr. F. P. Stearns followed with an account of the use of small pipe sewers in other sections of the country. Written discussions upon the same subject were read, which had been prepared by Mr. F. Floyd Weld, City Engineer, Waterbury, Conn.; Mr. G. T. Nelles, City Engineer, Leavenworth, Kan.; Mr. W. B. Pierce, Borough Engineer, Stamford, Conn.; Mr. A. R. Sweet, Engineer and Superintendent of Sewers, Pawtucket, R. I.; and Mr. George A. Kimball, Member of the Society.

President FitzGerald gave a brief summary of an article on sewers in the February, 1888, numbers of the *Annales des Ponts et Chaussées*.

Verbal discussion followed the reading of the several communications, in which Messrs. Aspinwall, Clarke, French, Fuller, Manley, McClintock, Smith, and Stearns of the Society, and Mr. A. R. Sweet, of Pawtucket, R. I., took part.

On motion of Mr. Howe, the Secretary was instructed to tender to the Treasurer of the Chadwick Lead Works, and to the Superintendent of the Boston Heating Company, the thanks of the Society for the courtesies extended on the occasion of the excursions to those works; also, the thanks of the Society to the gentlemen who have contributed written discussions to the evening's exercises.

[Adjourned.]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 2, 1888 :—292d Meeting.—The Club met at Washington University at 8:10 P. M., President Holman in the chair, thirty-four Members and three visitors present. The minutes of the 291st meeting were read and approved. The Executive Committee reported its meeting of the same date, approving the application for membership of Prof. A. E. Phillips. He was balloted for and elected. The Secretary announced the application for membership of Wm. T. Gould, indorsed by C. H. Sharman and I. A. Smith ; referred to the Executive Committee.

Prof. Nipher, Chairman of the Committee to which was referred the communications on National public works, asked the Members to present any information they might have on the subject. Copies of Part 1 from the Council of Engineering Societies were distributed.

Professor Johnson, Librarian, reported the completion of an index of the Club's books and pamphlets, including publications received by the index department of the Association, which had been presented to the Club.

Mr. Wheeler read the action of the Engineers' Club of Kansas City on the subject of improvements in highway bridges. The St. Louis Club was asked to co-operate in securing needful legislation. On motion the matter was referred to a committee of three. The chair appointed H. A. Wheeler, C. H. Sharman and M. G. Schinke such committee.

A communication was read from J. A. Ockerson, resigning the office of vice-president on account of continued absence from the city ; on motion accepted. Col. E. D. Meier and J. A. Seddon were nominated to fill the vacancy, the latter withdrawing his name ; the election to be by letter ballot and the result reported at the next meeting.

Col. E. D. Meier then read a paper on "The Prall System of Distributing Heat and Power from Central Stations." He called attention to the low efficiency of methods heretofore employed, and gave a detailed description of the Prall system, which he believed offered a solution of many of the difficult problems involved. Water was heated to a high temperature and then pumped through the pipe system at greatly increased pressure. At certain points it was converted into steam or water at lower pressures for heating, power, cooking or other uses.

The subject proved of very general interest and was discussed by Messrs. Wheeler, Nipher, Blaisdell, Woodward, Jones, Seddon, Gale and White. The practical trial of the system at Boston during the past winter had resulted favorably, and extensions were now being planned.

The hour being late Mr. White's paper was made the special order for the next meeting, May 16th. Adjourned.

WM. H. BRYAN, Secretary.

MAY 16, 1888—293d Meeting:—The Club met at Washington University, at 8.20 P. M., twenty-eight Members and nine visitors present. The President being absent, the Secretary, by consent, read the report of the Executive Committee meeting of same date, approving the application for membership of Wm. T. Gould and announcing the resignation of Geo. E. Otis. The election of Col. E. D. Meier to the Vice-Presidency of the Club was announced. The Committee reported having arranged the last meeting of the spring session for May 30 instead of June 6. Vice-President Meier then took the chair. On balloting Wm. T. Gould was elected to membership. The Secretary announced the application for membership of Edmund Hall, indorsed by M. L. Holman and W. H. Bryan ; referred to Executive Committee. On motion the consideration of the reports of Special Committees was postponed until after the reading of the papers. Mr. Chas F. White then read a paper on "The Failure of a Firmenich Boiler." The disaster in question occurred at the Plant Flour Mills, Main and Chouteau avenue, St. Louis. The construction of the boiler and the arrangement

of the plant, together with the method of operation, were described. The material used was C. H. No. 1 iron of 45,000 pounds tensile strength. Test specimens had shown a tensile strength of from 50,100 to 58,900 pounds. The boiler had 3,375 square feet of heating surface and was rated at 225 horse-power. In the opinion of the speaker the failure was due to faulty design, which permitted great differences of temperature and consequent expansion of adjoining tubes, as well as danger from scale. Comparisons were made with other prominent water tube boilers. Messrs. Meier, Wheeler, Russell, Blaisdell, Nipher and Johnson took part in the discussion.

The second paper was read by Mr. Louis Stockett on "A Well Ventilated Mine." The proper ventilation of mines was such a simple matter that it was a cause for surprise that it was not better done. Mr. Stockett described in detail the arrangement at Mine No. 6, Staunton, Ill., illustrating his remarks with drawings. The difficulties met with and their remedies were pointed out.

After a short discussion the reports of special committees were taken up. The Secretary read the following:

To the President and Members of the Engineers' Club of St. Louis:

GENTLEMEN: Your Committee to which was referred the matter of "Proposed Legislation on National Public Works," beg leave to report that they have carefully considered the matter, and report as follows:

1. That we are of the opinion that the proposed legislation as laid down in the Cullom-Breckenridge bill is a step in the right direction, and that if properly carried out will result in substantial improvement in the efficiency of this branch of the public service.

2. We recommend to the Club the appointment of two committees, one of which shall be charged with the duty of raising funds as requested by the Executive Board; that this money be raised by private subscription from members of the Club and others who may be interested in the matter.

We recommend that the other committee be instructed to correspond with similar committees from other clubs and with any other persons who may be able to aid in bringing the merits of the proposed legislation to the attention of Members of Congress, the object being to secure concerted action in urging the passage of the proposed bill as it may be finally perfected.

We are of the opinion that promotions from the grade of Division Engineer to Department Engineer should be subject to the recommendation of an examining board, as provided for the grades of resident, first assistant and second assistant engineers; and we therefore recommend that the club pass a resolution to this effect, and that the Committee on Correspondence be instructed to forward this resolution for the consideration of the Committee having the bill in charge.

[Signed]	FRANCIS E. NIPHER,	} Committee.
	A. W. HUBBARD,	
	S. B. RUSSELL,	

On motion, the report was received. Moved and seconded to make the consideration of this report the special order for the next meeting. Lost. Moved and seconded to adopt the report of the Committee. After discussion by Messrs. J. A. Seddon, Eayrs, W. L. Seddon, J. B. Johnson, Nipher, Meier and Russell, the motion was carried. On motion the action required by the recommendations contained in the report was made the special order for the next meeting, May 30.

[Adjourned.]

WM. H. BRYAN, Sec'y.

WESTERN SOCIETY OF ENGINEERS.

MAY 9, 1888:—The 247th meeting was held, the President in the chair.

The minutes of the last meeting were read and approved after the following change had been made. The Memorial to Congress was reconsidered, and the first "Whereas" amended to read as follows:

"The system under which our National Public Works are conducted is subject to

severe and just criticism, being without a well-considered policy or a consistent purpose."

The Secretary reported the receipts to date as \$719.59. The Secretary and Treasurer's statements showed cash on hand, \$190.12. Bills for \$331 were presented and ordered paid.

Application for membership was received from Lewis R. Jackson, Chief Engineer J. A. & N. Ry., E. J. & E. and G. C. C. & N. Ry., Chicago, Ill.

Resignations were received from E. H. Beckler and John Herron, Helena, Montana, on account of the organization of the "Montana Society of Civil Engineers," of which they have become Members. Resignations accepted.

A communication was received from Mr. T. J. Nicholl, Vice-President and General Manager Natchez, Jackson & Columbus Railroad, accompanied by a letter from the Pennsylvania Steel Company, advocating the use of rails 33 $\frac{1}{8}$ feet long as standard, as cars are now 34 feet. After an informal discussion, the letters were ordered placed on file.

Letter from the Secretary of the Engineering Society, University of Toronto, Toronto, Canada, requesting an exchange of Proceedings, was referred to Secretary for reply. The Secretary was also instructed to reply on behalf of Society to invitation of L. M. Johnson, Eagle Pass, Texas.

The following report was received from Committee on Highway Bridges:

The Committee on Highway Bridges, in its report, read at the meeting of the Society on March 6th, made the following recommendations:

"We think that improvement in the character of highway bridges can be brought about by the following means:

"The Governor of each State to appoint an engineer, whose duty it shall be to examine and report on existing bridges, with authority to condemn unsafe structures, and to act as expert adviser to the Legislature on all questions and measures pertaining to the construction of new work.

"Cities and counties should be encouraged to employ engineers who are bridge specialists to prepare specifications and complete detail plans for bridges, and tenders from contractors should be received on the basis of these specifications and plans. In order to facilitate the adoption of this method, we think it highly desirable that engineers agree upon a scale of minimum rates for doing such work on a similar plan as in vogue among architects."

The Committee was continued with instructions to report the best practical means for carrying these suggestions into effect.

We now beg to submit the following supplemental report :

Inasmuch as we think it desirable that any action taken shall be, as far as possible, the joint action of all organizations similar to our own, we recommend, as a step preliminary to such joint action, that the Secretary be instructed to place himself in communication with other local engineering societies, and request from them an expression of opinion on the subject under consideration.

Respectfully submitted,

C. L. STROBEL.

A. GOTTLIEB.

E. C. CARTER.

The report was discussed at length by Strobel, Williams, Cregier, Gottlieb, Bates, Parkhurst and others, and finally referred back to Committee, with instructions to correspond with other societies with a view to an expression of opinion and ultimate co-operation.

The question of permanent quarters, and generally of placing the Society upon a more substantial footing, was then taken up. The feasibility of accomplishing material results was generally conceded. The Trustees were requested to consider the whole question and report a definite line of action.

The reading of papers was postponed until next meeting.

[Adjourned.]

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

APRIL 10, 1888 :—The meeting was called to order at 8:10 P. M., President Whitelaw in the chair; 13 Members present. The minutes of the last meeting were read and approved.

The following resolution, offered by Mr. Sam. J. Baker, was adopted and ordered to be spread upon the minutes :

Whereas, Mr. M. E. Rawson has lately retired from the position of member of the Board of Managers of the Association of Engineering Societies after six years of service devoted to the interests of the Club and the Association which he was largely instrumental in founding and perfecting ; therefore,

Resolved, That the hearty thanks of the Club are hereby tendered to Mr. Rawson for his valuable services in its behalf.

Mr. Whitelaw then announced the appointment of the following committees :

Civil Engineering and Surveying—Walter P. Rice, August Mordecai, J. D. Varney, John L. Culley, H. B. Strong.

Mechanical Engineering—Ambrose Swasey, John Walker, J. L. Gobeille, E. H. Jones, Alex. E. Brown.

Architecture—F. A. Coburn, C. F. Schweinfurth, C. O. Arey, J. M. Blackburn, J. N. Richardson.

Railroad Engineering—H. C. Thompson, W. H. Searles, H. F. Dunham, B. F. Morse, M. W. Kingsley.

Applied Science—E. W. Morley, N. B. Wood, N. M. Anderson, George Bartol, G. A. Hyde.

A communication was read from Mr. H. F. Dunham requesting President Whitelaw and Mr. M. W. Kingsley to extend to the American Water-Works Association meeting in Cleveland, April 17, 18, and 19, a cordial and valuable welcome. Mr. Dunham suggested that a description of the water-works of Cleveland should be given. Mr. Whitelaw assured the Club that he would do all in his power to give the Association an appropriate welcome.

Mr. Whitelaw then said that it was expected that some action should now be taken with regard to the death of Charles Latimer, late President of the Club.

Mr. H. C. Thompson said that in view of Mr. Latimer's connection with the Club from the beginning, the interest he had always manifested and his prominent position as an engineer, he thought it would be fitting to hold a special meeting at which some member of the Club should deliver an eulogy, and that in addition a committee should be appointed to prepare a set of appropriate resolutions, to be engrossed and presented to his family and to be spread upon the minutes. Mr. Thompson therefore moved that such action should be taken.

Mr. Gobeille said that he would like to amend that resolution by adding that this committee should prepare a sketch of Mr. Latimer's life, to occupy not less than six or eight pages of the JOURNAL, referring specially to the subjects in which he was most interested.

Mr. Thompson said that he had thought that the eulogy would cover the whole of the ground; he would accept the amendment.

Mr. Whitelaw said that he thought that many persons not connected with the Club would be glad to attend the meeting suggested, and to pay their tribute to the memory of Mr. Latimer. He thought that it would be well to fix the time of the meeting for two weeks from the present meeting.

Mr. Thompson said that he would include in his motion that the time should be two weeks hence, at the usual semi-monthly meeting.

Mr. Whitelaw said that if outsiders were invited it would require a larger room than that of the Club.

Mr. Varney said that he thought the motion should be carried with the understanding that the president should obtain a larger room if he considered it best and announce the place of meeting in the papers.

Mr. Whitelaw asked if Mr. Varney did not mean that the president should take this action in conjunction with the Committee on Resolutions.

Mr. Varney moved that this should be a part of the duties of that committee.

Mr. Thompson's motion with amendments carried.

Capt. A. Torrey, of New York, then read a paper in favor of sheet or asphalt pavements compared with stone.

Mr. Whitelaw appointed as the Committee on Resolutions for Mr. Latimer, Messrs. A. Mordecai, H. C. Thompson, W. H. Searles, James Ritchie and J. L. Gobeille, Mr. W. H. Searles to be asked to deliver the eulogy.

[Adjourned.]

JAMES RITCHIE, Secretary.

PROCEEDINGS OF THE MEMORIAL MEETING OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND, HELD IN THE ROOMS OF THE BOARD OF EDUCATION.

APRIL 24, 1888 :—The meeting was opened by prayer by the Rev. B. T. Noakes, President Whitelaw in the chair. About forty Members and friends present, including ladies.

The report of the Committee on Resolutions was read by Mr. A. Mordecai, chairman of the committee, as follows:

Some one has said that language was made to conceal thoughts, and on such an occasion as this it seems so entirely inadequate to explain one's feelings that we are forced to give our assent to the paradox. How can the few words in the resolution which I will present convey to any one either that feeling of loneliness caused by the loss of the encouragement and sympathy of one of the kindest of men, or the deep grief felt that we have had to say farewell forever to a heart so good and true as was Mr. Latimer? We did not realize how we valued him until he left us. Associated as I was intimately with him for a period of over fifteen years, I learned to admire him for his integrity, his fearlessness in doing what he thought right, his strong practical common sense, and to love him for his warm-hearted sympathy, his simple and pure character. He had his faults—who of us have not?—but they only served to make his virtues more prominent. It is asked, "Is life worth living?" Yes, a thousand times yes, if we have, or can leave behind us, the record of a life spent in the effort to do good to our fellow men, the purity and integrity of character, the devotion to principle, the full human sympathy that made Mr. Latimer beloved by all who knew him, and caused hundreds that did not know him to feel the shock of his death as that of a personal bereavement. In an effort to express our feelings, vain though it be, on behalf of the committee, I submit the following resolutions:

Wishing to express our sorrow at the death of Mr. Charles Latimer, late a Member of this Club, and our sympathy with his bereaved family; be it

Resolved, That, First.—By the death of Mr. Latimer we lose an upright and conscientious man, whose honest and pure character, intense earnestness in everything pertaining to the welfare of the community, and great desire to do right as he understood it, made him, in all respects, and exemplary citizen. While true and zealous in his particular religious belief, his mind was large enough, and his heart charitable enough to make him tolerant of the beliefs of others.

Second.—A successful engineer, his works proclaim his ability. His large sense of justice, his sound practical judgment, and his ever ready sympathy with the feelings of the very humblest of his subordinates made him one of the most successful of executive officers. His loss will be felt most keenly by those with whom he was most intimately associated.

Third.—One of the original members of the Civil Engineers' Club of Cleveland, and one of its ex-presidents, he always took the greatest interest in its welfare, ever willing to give his advice and his time in furthering its objects. Possessing great originality of thought, the papers read by him from time to time have always been most valuable and interesting.

Fourth.—To his bereaved family we tender our heartfelt sympathy at the loss of such a loving father, such a kind and devoted friend. Of simple and domestic habits, he was never happier than when contributing to their pleasure.

Fifth.—That the resolutions be spread upon the minutes of the Club, and that they be engrossed and sent to his family.

The resolutions were unanimously adopted.

Mr. W. H. Searles then read a eulogy on the life and character of Mr. Latimer, having been selected for that service at the previous meeting.

Mr. Searles was followed by Mr. L. A. Russell, who said :

"I esteem it a high honor that I have been requested to say anything in this memorial service to Charles Latimer. It was my happy fortune for many years to be so brought in contact with him that I came to understand him well. I had ample opportunity to observe his disposition, motives, and conduct in life. I was associated with him in the same line of important business, yet in an entirely different department. We were as brothers working for the same object, yet each in his own way and thoroughly independent of each other. I could not but understand his character, and understanding it as I do, I have for that character nothing but admiration. He was interested in many things, and profoundly sincere in his devotion to them, in which I took no interest whatever, but that he believed in them most thoroughly I never had room to doubt for one moment.

I knew that he had a wonderful gift in the application of the divining rod. It was demonstrated before me. I could not comprehend it, but I saw the effect. I did not know by what mysterious power his mind was informed of facts that to my mind were incomprehensible, yet I know that in him there did dwell a power that gave him an insight beyond the ken of ordinary minds, not by means supernatural, but by the natural exercise of faculties that he possessed. He would take any ordinary forked twig of witch hazel, or of other wood, and walk over a piece of ground, and as he passed over the spot where that influence, whatever it was, existed, the twig would turn in his hand, sometimes with such force that the bark would be torn off. There hung over the gas jet at my desk for many years a witch hazel twig upon which I had observed the twisting of the bark as it came from his hands. He could not explain by what influence he was able to discern how many feet below the surface of the earth lay the substances of which he was in search. Like the striking of a bell that marks the hours, there seemed to come to him that knowledge of numbers and distance. It was not so remarkable that he should know that certain substances lay beneath the ground, but that the moment the twig turned in his hand he could discern the depth of the substance, seemed to me a mystery that bordered on the supernatural.

With that idea of his power with the divining rod, I had no quarrel, that was not to me folly, it was demonstrated to me as a fact ; but when he called upon me to accept the belief that the Almighty Creator had appointed that his creatures should take as their unit of measure and as the foundation of their standard of measures, a measure found in the great pyramid of Gizeh, then I wholly disagreed with him. But that he believed that Almighty God had divinely appointed the British inch as the unit of measure for the Anglo-Saxon world, through inheritance, and then for the whole world, I never for a moment doubted ; and that Charles Latimer abhorred the French metre, looked upon it as an abomination and a sinful thing, was undoubtedly true.

Charles Latimer was as pure a man in his motives, in his conduct, in his deportment toward his fellow men as I have had the pleasure of meeting on the face of the earth. He had always with him an abiding faith in Almighty God that was touching to behold. I did not believe in it; I do not believe that Almighty God counts every hair of the man's head and orders every step that he takes, but Charles Latimer never doubted all this. He believed, too, that if Almighty God intrusted him with any earthly treasure, it was only his to give away, and his one

grief was that his Creator did not see fit to bestow upon him goods to give away, so that he might make easy the yoke of every heavy laden child of his Father. I expostulated with him. I knew that I could not move him by any presentation of motives of worldly expediency, so I charged him with sin in giving away what was bestowed upon him for the purpose of providing for his own. With the greatest nonchalance in the world he repelled the accusation, and said that Almighty God was just as competent to take care of his (Charles Latimer's) children as he was to take care of Charles Latimer himself. With my experience of him, his money always went faster than it came; he always had a place waiting for his beneficence.

I was thrown with him in places where if he had felt any desire to accomplish wrong he could certainly have done it. I was thrown with him where there were constantly matters of controversy, and if the element of seeking to overreach or to do injustice had been in his character, I could not have failed to see it. I say it before his peers, before his fellow workers, that I never saw Charles Latimer undertake to accomplish the very least injustice, nor could there be found in him a desire to gain any unjust advantage. I have seen him many times upset the schemes of the corporation for which he worked by his perfectly sublime adherence to the truth. He could not swerve from his adherence to the truth as he saw it in favor of the corporation for which otherwise he worked so devotedly. It might be said of him as it was of that Roman of old: "It were as easy to turn the sun from his course as thee from the path of duty." If a case could not be won except by getting Charles Latimer to swerve one iota from the truth as he saw it, that case was lost. If he thought that a point should not be sustained, he would give it away squarely and openly. No thought of favor or possibility of disaster to himself could move him. He stood firm in his conviction of right.

He abominated work on the Sabbath day, as far as men under him were concerned; he led many of them to allegiance to his belief in the wrong of it. He abominated the habit of the use of intoxicating drinks, and worked steadfastly to abolish it.

I am well satisfied that the thing that made him a successful engineer was not scientific attainment as an engineer: there are many men in this room who have greater scientific attainments. The secret of his wonderful success lay in his power over other men, which he possessed in a remarkable degree, not through any occult influence, but by the exercise of justice towards those men and sympathy with them. The track force of any railroad is not remarkable for spirituality, or piety, or any other virtues. Over these men Charles Latimer exercised a wonderful power. He increased their morality, he raised the standard of work among them by teaching, by example, and by means of those periodical assemblies of his track force known as "roadmasters' meetings," of which he was the originator. There everything in relation to roadbed was freely discussed, and every man had an equal right to the expression of his opinion. Every section hand in his employ was an interested member of the best school of track engineering I have ever known. He accomplished results in which a more scientific, a more thoroughly trained engineer, would utterly have failed. The devotion of the men in his department to the highest excellence in their business because that devotion would please Mr. Latimer, would satisfy his standard, was wonderful. The roadbed under his direction was changed from a condition of neglect to one of perfect order in the smallest details. During his administration, up to the time he left it two years ago, no accidents occurred—no accidents could occur, the caretaking was so thorough.

He was a man of peace. Such strikes as have been rife in the land were never thought possible under his administration. A strike must be caused by injustice in some form, and how could men strike against Charles Latimer, who would

never do injustice, or suffer it to be done? He did to the laboring men as he would have them do to him, and the time is not far distant when the necessities of the case will make others follow where he led. I have known many preachers of the Gospel who made preaching the work of their lives, who have accomplished less as teachers of righteousness than Charles Latimer.

Rev. B. T. Noakes, D.D. : I did not expect to say a word to-night, having already spoken at the funeral of our lamented friend, and I can add nothing except the expression of my heartfelt thankfulness that God saw fit to place in our midst such a man. It is a blessed thing to see a good man ; it is better to love one. If anything has been lacking in what has been said to night it is simply this: Let us give God the praise for the life of the man who has gone before us, for it was the development of the Holy Spirit incarnate in him ; it was God working mightily in him that made him what he was. He would have been ashamed to do wrong for fear of dishonoring his Saviour. His latent thought was, Christ in me the hope of glory. I am profoundly thankful that God in His grace permitted me to know and to love His faithful servant, Charles Latimer.

M. J. McNarna : It was my good fortune and an honor that I have always appreciated to be associated with Charles Latimer for about 19 years. I first met him on the shores of Lake Michigan. He was at that time assistant engineer of the Chicago & Michigan Lake Shore R. R., and I was roadmaster. He made an inspection of my work, and when we were better acquainted he made me an offer to leave that road and go with him. This I accepted, and I have always been glad that I did so. He was the noblest and grandest man I ever saw. I have seen him under many provocations, and I never heard him utter an unjust word.

About three weeks after he had engaged me he said: "One thing I particularly wish you to understand; that is, that no man who works for me must indulge in intoxicating liquors. I do not wish to discharge the men, but we must teach them to abstain." Soon after he came to Ohio he was appointed principal assistant engineer on the A. & G. W. R. R., and he offered me a position there, which I accepted. He told me that we must make an effort to do all our work for the maintenance of the track department on week-days. I tried it and succeeded.

Then came the undertaking of the changing of the gauge. The stockholders thought it best to do that work on Sunday. He did not agree with them. They said that if the work was done on a week-day the trains would be detained. He replied that he would guarantee that not more than one train would be detained. It was finally decided that the work was to be begun at four o'clock on the morning of the 22d of June. He sent us various telegrams the night before pertaining to our work. The last came at midnight. It was a prayer for guidance in our work. At four o'clock in the morning we drove the first spike ; at 6:55 o'clock the last spike was driven and the gauge was changed.

Though I grieve for the occasion that calls us here to-night I am glad to give expression to my feelings and to offer a word to the memory of my friend. I express not only my own feeling, but that of a class of men whom Charles Latimer loved. He took pride in calling us the "knights of the pick and shovel." We cannot say that he is dead. His memory will live as long as the whistle of the iron horse that passes over the railroads of the United States is heard. It will live in the hearts of the trackmen of this country, and help them to keep their faith in God and man. He was fully awake to the interests of these men ; fully in sympathy with them. The moment you grasped his manly hand you knew that he spoke to you from the heart, you knew at once that he was your friend, and in my sorrow I am thankful that for so many years I could call him "friend."

Dr. J. Edwards Smith : It was not my intention to say anything to-night, but there seems to be something left unsaid, one element in the character of our friend that has been passed over. I have known Mr. Latimer for the past ten years. I was a member of the Anti-Metric Society, and in many instances I opposed his

pet theories. The crowning element in his character was his boundless love towards all mankind, without reference to sect, station or nationality. He was surrounded by an atmosphere of love. It was impossible to be in his presence for fifteen minutes without feeling one's self a better man. At times we had our disagreements in opinion. I fought some of his theories. In some of these arguments I became nettled and said some pretty rough things to him, but it was like the splashing of an angry wave against a rock on shore. He would listen with his eyes beaming with kindness, and after I had said all that I desired, he would sit down and talk with me just as before. I do not believe it is possible to point out a human being that Charles Latimer ever tried to belittle by word or deed.

Not more than two days before his death I met him near my office. He made the remark that he was nearly sixty-one years old, just in the prime of life. I asked him some question about his health. He answered, "I am all right," but, he added, "in the midst of life, we are in death," and so it proved.

Mr. W. R. Warner: I have been thinking of one of our late meetings, where Mr. Latimer read a paper in reference to an invention mentioned by Mr. Searles. Some of the younger members opposed his statements and seemed to claim precedence in the invention, but he appeared unmoved, and by his calm and manly demeanor he won the Civil Engineers' Club to his side.

He has taught us something. He was an earnest man and we appreciate earnest men nowadays. He was a genuine man, he was genuine in everything he said or did. We can learn something from that. We can all be better engineers and better citizens for having known him. We can be better men and purer men. For the loss of this influence in our midst we mourn him to-night.

Mr. Whitelaw then read a memorial letter from Mr. J. H. Holloway, as follows :

To the Members of the Civil Engineers' Club of Cleveland :

Claiming, as I do, participation in your festivities, I ask as well a place with you when sadness rules the hour. It has not been my privilege to know as intimately and as long our departed friend and brother as many members of our Club have, but no one needed to know Charles Latimer either long or intimately to be assured of his honesty, his earnestness and ability.

In his goings in and out before this Club, as a Member or as President; in the position of power and importance which he so long held as the chief engineer of one of the most important railway lines of this country ; in his place in society and in the church, he developed no traits of character we cannot admire; has left no records we should not wish to emulate

Like many of the older members in that branch of engineering which he pursued, he had had many and varied experiences, and yet notable as many of these were, how modestly he always referred to them.

As an organizer of men and methods he was remarkably successful. Of his helpfulness to the younger members of his staff there are many who can testify, and there are many engineers who to-day are holding positions of importance and responsibility who, for the aid they have received from him in the past, will hold his memory dear.

But his skill in organizing, and his earnest desire to aid and benefit others, was not alone confined to his staff of engineers, it had a wider, broader field.

I love to think of him not only as a man who gave to the minutest details of construction, and to the repair of everything pertaining to the railways under his charge, which could add to the comfort or insure the safety of its patrons his most careful thought and study ; but who sought as well to lift to a higher plane the men who before had simply been looked upon as instruments by which the thoughts of others were to be carried out.

Among the many things which mark his kindness of heart, and his wisdom as well, was the originating and, during his term of office, keeping up the annual

gathering of the men who had charge of the laying of the tracks, keeping up the grades, maintaining bridges, etc., where each man was induced not only to take a pride in his own work, but also discuss with others the best methods by which to produce the best results.

We all know our departed friend too well to believe this was done simply as a matter of policy; true, it was of great benefit to the railway of which he had charge, but beyond that, and above that, was the wish to awaken in these men thoughts and aspirations of something higher than the mere mechanical labor involved; and there stood about his open grave no more sincere mourners than these men whose lives he had thus benefited.

There is one phase of our dead brother's life of which I desire to say a few words, and yet I approach it with something of misgiving. It was our wont in times past to make it one of our pleasantries, but I am sure that no one, even in his merriest moods, ever forgot or failed to honor Mr. Latimer's honest purpose, his devoted self sacrifice, a purpose that was never turned from his steady, onward tread, by success or failure, by incredulous smiles, or pursuing poverty. He gave to it hours many of us thought should have been given to rest; he gave to it study and thought, which we believed in other directions might have better served the world, and better served himself; he gave to it his means, which many of us thought should have been laid aside to smooth declining years. Need I say that this was his honest opposition to the introduction of a system of measurement, the origin of which he deemed impious; that it was his devotion to the study and investigation of that ancient treasure pile, the Great Pyramid of Gizeh, in which he felt there was stored for our time, and for all time, measurements that were divine.

It was, I think, for many years the light that led him on, the hope that sustained him when many others failed, that some time or other he would himself climb to the Pyramid's highest peak and delve into its innermost depths; that with his own hands he would touch its polished stones, venerable in their age, sacred in their purpose. What visions there came to him as he dreamed of this time, then seemingly so far off, now never to come to him in this life, we shall never know, but we can believe that in his studies and his reveries he fancied that once on that sacred spot he would be able to find some hitherto undiscovered key for ages hidden from mortal sight, which found, would open up treasures of truth and knowledge, saved through all generations past for our time and for our generation.

On that Sabbath morning, when dawning light found him on bended knees with closed eyes, and thoughts turned heavenwards, that key was found—it opened for him the portals of immortality, it revealed to him boundless knowledge of the hitherto unseen—it was death.

Mr. Whitelaw: Some two or three years ago, returning from church with Charles Latimer, we spoke of the inspiration of the builders of the pyramid. I offered the suggestion that as our Saviour sojourned some time in Egypt it was strange that he did not speak of the pyramid afterwards if it was a divinely appointed building. His answer was ready and apt. He said that Christ came into the world to teach spiritual things and that the pyramid was a record of material things. I have often thought since his death of a writing of Proctor, where a man who has passed into the other life is taken by an angel and shown all the stars. I have thought that if in the spirit world the interests we feel here may be continued, one of Mr. Latimer's first desires would be to visit the pyramid and explore its mysteries.

The papers that have been read here to-night have certainly been most gratifying in their tribute to Mr. Latimer's character, and I should like to have a permanent record of them in our JOURNAL.

N. B. Wood: Much has been said to-night with regard to the sweetness of Mr.

Latimer's character. I did not regard him as one of those sweet and loving men who never felt anger. In fact, I know otherwise from personal experience. I will mention one incident with regard to this. I belong to the Anti-Metric Society, and had presented to it a very fine weighing apparatus, and had invited a friend to go with me to a meeting where it was intended that I should exhibit it. My friend and I in one part of the room became so earnest in discussing the merits of the weights that we interfered with those who were discussing the pyramid. The next day a little article came out in the papers, characterizing my friend as a dilettante professor. I replied through the same channel that Professor ——— was a man well known to the scientific world, that he had taken his degree, and was a teacher in one of the leading colleges. Another reply came out in the paper, and finally we had quite a newspaper war. Then a letter came to me from Mr. Latimer saying that we could not afford to quarrel over a matter of that kind, and that he would make apology for what he had said. I replied in the same spirit, and the next time he met me he gave me a hearty grasp of the hand that showed that all anger was banished. He had that intensity of feeling which would make him sometimes aggressive, and which would have made any other man of his disposition offensive; but on sober second thought he always made amends for any hasty word. I have not mentioned this because there has ever remained in my mind a trace of animosity towards him. I had for him the warmest feeling of friendship, but it seems to me that the man who could control, as he constantly did, his own impulsive nature, was far more worthy of our admiration than if he had merely possessed that sweetness of disposition which is often only a negative virtue. He conquered himself by the governing principle that was the foundation of his character, and it was a grand character.

Mr. J. L. Gobeille moved that the papers and reports of the various speakers be spread upon the minutes and published in the JOURNAL. Motion seconded and carried.

[Adjourned.]

JAMES RITCHIE, Secretary.

MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

MAY 2, 1888:—Regular meeting at the Board of Education rooms, 8 P. M., Vice-President Sublette in the chair. Minutes of the last meeting were read and approved.

It was voted to dispense with the regular order of business and take up Mr. Abbott's paper on "The Intake Pipe at St. Cloud." On motion the paper was ordered printed in the JOURNAL of the Association.

[Adjourned.]

WALTER S. PARDEE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

MAY 7, 1888:—A regular meeting was held in the Club-room at 7:45 P. M. There were present Messrs. Frank Allen, W. H. Breithaupt, E. Butts, W. D. Jenkins, E. B. Kay, A. J. Mason, S. A. Mitchell, G. W. Pearsons, E. J. Remillon, C. E. Taylor, F. W. Tuttle, F. R. Tuttle, C. S. Wade, T. F. Wynne, K. Allen and five visitors.

Minutes of the adjourned meeting of April 16 were read and approved.

On a canvass of ballots the following were declared elected as Members: Daniel Bontecou, O. B. Gunn, E. I. Farnsworth, Alexander Potter, M. N. Wells, Wm. B. Upton; as Associate Members, H. F. Hill, F. C. Florance.

The Secretary read two communications from Mr. B. W. DeCourcy, of Independence, Kan., describing some piers and abutments recently erected in Montgomery County, Kan., which had failed or were considered unsafe, also a bow-

string girder in the same condition, stating that the county had lost considerable money in neglecting to procure professional advice. The Secretary presented for Mr. DeCourcy two photographs of the work with specimens of the stone. The Secretary made a few remarks on the above masonry, which he had been called upon to inspect, and presented results of tests of the stone made by Prof. J. B. Johnson, of St. Louis.

Mr. Donnelly being unable to present his paper on Kansas City Pavements, Mr. Mason gave a brief description of those in use here, and especially of the Trinidad asphalt pavings, a specimen of which, from one of the Omaha streets, he presented to the Club. Mr. Mason believed that asphalt would eventually be the principal paving material used here on account of its durability, the ease with which it could be kept drained, and as it is found to be serviceable on grades as steep as 8 per cent.

After discussions by G. W. Pearsons, C. S. Wade, T. F. Wynne, E. B. Kay, H. Goldmark, W. D. Jenkins and K. Allen, the following were proposed as members: A. N. Connett, by J. A. L. Waddell and Wm. B. Knight; B. W. DeCourcy, by W. H. Breithaupt and Kenneth Allen; V. M. Witmer, by W. H. Breithaupt and E. B. Kay.

[*Adjourned.*]

KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

- Alloys, Copper-Tin.** A preliminary experimental research upon the mechanical properties of small castings of the alloys of copper and tin. Transverse, tension, torsion and compression tests in detail, with 81 plates and diagrams. By R. H. Thurston, Chairman. *Report Board of Testing etc.*, 1881, Vol. I., pp. 271-451.
- Angle Prisms.** Discusses the construction and uses of angle prisms. *Eng. News.*, May 12, 1888.
- Boilers, Pressure in Marine.** By Richard Sennett, before the Institution of Naval Architects. Discusses working and test pressures for marine boilers. *Engineering*, March 30, 1888.
- Boiler, Water Tube, Trial of a.** By R. H. Thurston. Gives very full details of a test of a Babcock-Wilcox water-tube boiler at Sibley College, Cornell University. *Sci. Am. Supple.*, April 14, 1888.
- Brake, Eames Vacuum.** Full description, with detailed drawings, of the Eames vacuum brake. *Engineer*, March 16, 1888. *Sci. Am. Supple.*, April 21, 1888.
- Bridge Inspection.** Gives the order to bridge inspectors in use on the Buffalo, Rochester & Pitts-burgh Railroad. *Engin. News*, May 12, 1888.
- Bridge Strains, Slide Moment Diagram for Computing.** By J. E. Greiner, before the Engineers' Society of Western Pennsylvania. Gives a description of a slide moment diagram, which has been in use in the Baltimore & Ohio office for three years, and is considered the best method of finding shears and moments in bridges. Abstracted in *Engin. News*, April 14, 1888.
- *Graphical Evolution of Stress in Lattice Girders.* By Wm. Robertson. Gives a comparison between the values of the stresses in the flanges of various forms of latticing as determined by their numerical evolution and the ordinate to the parabolic curves of moments, and deduces rules for graphical solution. *Engineer*, March 16, 1888.
- Bridge, Brooklyn.** Gives report of the Committee on Terminal Facilities, and the adopted plans for the terminals. *Engin. News*, April 21, *et seq.*, 1888. *R. R. Gazett* April 27, 1888. *Engin. and Build. Rec.*, April 21, 1888.
- *Removal of the Wells Street, Chicago.* Gives details of the moving of the Wells street draw-bridge, bodily, to its new position on Dearborn street. *Engin. and Build. Rec.*, April 14, 1888.
- *Poughkeepsie.* A series of articles on the erection of the Poughkeepsie bridge. *Engin. and Build. Rec.*, May 5, *et seq.*, 1888.
- Bridges, Floors of Street.** By Carl Gayler before the St. Louis Engineers' Club. Discusses the different kinds of floors in use and gives cost of the different classes used in St. Louis. *Journ. Asso. Engin. Soc.*, May, 1888.
- Cable Roads, Otto System.** Describes the installation prepared for the New Castle Exhibition, with illustrations showing details. *Engineering*, April 6, 1888.

BOOKS.

- BAKER, B.** Long and Short Span Railway Bridges. Illus. \$2.00.
BOW, R. H. Economics of Construction in Relation to Framed Structures. 332 diagrams. \$2.00.
GROVER, J. W. Railway Bridges. 37 colored plates, folio, cloth. \$12.50.
GROVER, J. W. Iron and Timber Railway Superstructures. Illus. folio, cloth, \$17.00.
SPOONER, C. E. Narrow Gauge Railways. Plates, 8vo, cloth. \$6.00.
UNWIN, W. C. Testing of Materials of Construction. Illus. \$7.00.
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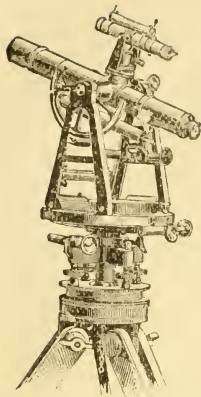
54 SACRAMENTO STREET, CAMBRIDGE, MASSACHUSETTS.

- Car, Twenty-five Ton Iron Ore.** Gives a two-page plate of detailed drawings of a twenty-five ton iron-ore car used on the Swedish Railroad. *Engineer*, April 27, 1888.
- Car Couplers.** Gives the contour lines, length of draw-bar and arrangement of dead-block for the automatic coupler as established by the committee of the Master Car-Builders' Association. *R. R. Gazette*, April 20, 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.
- Car Heating, Couplers for Steam.** A very full discussion of the subject by the New York Railroad Club. *Master Mechanic*, May, 1888.
- , *Winter's Lesson in Steam.* By Geo. Gibbs, before the April meeting Western Railroad Club. Discusses steam heating in the light of the experience of the past winter. *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888; *R. R. Gazette*, April 20, 1888.
- , *Steam.* A paper by Prof. Lanza, before the April meeting of the New England Railroad Club. Giving details of experiments made to determine the amount of steam used in heating passenger cars, with discussion. *R. R. Gazette*, April 20, 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.
- Car Wheels, Steel Tired and Chilled.** Extract from the report of the Massachusetts Railroad Commissioners on the Haverhill accident, showing the kind of wheels in use in Massachusetts. *R. R. Gazette*, May 11, 1888.
- Cement Mortars, Strength of.** By Prof. I. O. Baker. Gives tables showing the strength of cement mortar of various ages, compiled from a large number of experiments. *Eng. and Building Rec.*, May 5, 1888.
- Coal, How to Analyze.** An article describing the methods for the determination of the various constituents in coal which are considered best. *Engineer*, April 20, 1888.
- Concrete, Effect of Low Temperature on.** By P. M. Bruner before the Engineers' Club of St. Louis. Discusses the effect of low temperature on Portland cement concrete. *Jour. Assoc. Engin. Soc.*, April, 1888.
- Cranes.** Drawings of a twenty-five-ton wharf crane and a three-ton locomotive crane in *Engineer*, April 6, 1888.
- Drainage Tables.** By G. H. Johnson. Gives tables showing the diameters of circular pipes of given length which will discharge given volumes of water per second under a given head. *Engr. News*, May 5 and 12, 1888.
- Dynamos and Motors, Designing and Calculating.** The most practical method of designing and proportioning dynamos yet published. Francis R. Crocker. *Electrical World*, April 28, 1888.
- Electric Light, Maximum Efficiency of Incandescent Lamps.** A paper read before the American Institute of Electrical Engineers, April 10, 1888, by John W. Howell. A valuable contribution to electric lighting literature. Illustrates how to determine at what candle-power it is most economical to operate any given lamp and determines for a particular Edison lamp that it is working at its maximum efficiency when the cost of the lamp is 15 per cent. of the total cost of operation. *Electrical World*, April 14, 1888.
- Electric Meter, Thomson's.** An electric current meter for continuous or alternating currents, invented by Prof. Elihu Thomson. The vaporization of a volatile liquid by the heat of the current is employed to effect a reciprocating motion, which is registered by a train. *Electrical World*, April 28, 1888.
- Electrical Subway, New York.** Gives a good history of the Board of Electrical Control of New York City and its work. *Eng. News*, April 21, et seq., 1888.
- Engine, Compound Corliss.** Gives a brief description with two-page plate, and other engravings, of a compound Corliss engine. Cylinders 40 x 70 in., stroke 72 in., 2,500 indicated horse-power. *Engineering*, April 16, 1888.
- , *Gas, Griffin.* Gives details of experiments with a Griffin gas engine. Showed a consumption of 18.86 cub. ft. per hour per horse-power. *Engineering*, April 13, 1888.
- , *Horizontal Corliss.* Gives two-page plate and short description of an 18 x 48 Corliss engine. *Engineering*, April 20, 1888.

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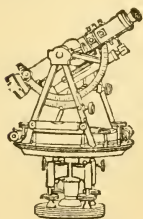
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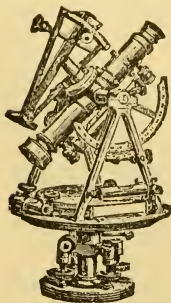
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INDEX DEPARTMENT.

Flow of Water in Mains, as Determined by Pressure Gauges. A paper by George A. Ellis, showing how the flow in pipes may be estimated from the loss of head. *Jour. New Eng. W. Works Assoc.*, September, 1886.

Foundry Work, Estimating Cost of. By G. L. Fowler, before the American Society of Mechanical Engineers. Gives outlines of a plan used by the writer to find the cost of castings. *Am. Eng.*, May 9, 1888.

Forced Draught, Closed Stakehold System. By Thos. Soper, before the Institution of Naval Architects. Gives a discussion on the use of forced draught under boiler in the closed stakehold system. Contains the experience gained with vessels in the British Navy. *Engineer*, April 6, 1888; *Engineering*, April 6, 1888.

——. By J. R. Fothergill, before the Institution of Naval Architects. Give the results of trials made with forced draught on the steamers "Marmora," "Dania" and "Elua." The summary shows a slight reduction in speed, with a saving of from 20 to 30 per cent. in fuel. *Engineer*, April 6, 1888; *Engineering*, April 6, 1888.

Fuel, Petroleum Oil as. Gives a report of the tests made at the Salem pumping station, to test the value of petroleum as fuel, when converted into and used as gaseous vapor. The oil was found more economical than coal. *Am. Manuf.*, April 6, 1888.

Gas. An Oil or Gas Well Rig. A good description of the ordinary apparatus for drilling for petroleum or natural gas. *Age of Steel*, April 14, 1888.

——, *Water.* By G. H. Christian, Jr., before the Ohio Gas Light Association. Gives the results of experiments to substitute Lima crude oil for naphtha in the manufacture of water gas. *Am. Manuf.*, April 20, 1888.

Gun, Pneumatic. See Ordnance.

Harbor. Karachi, India. Gives memorandum of works in progress as proposed at an early date for the improvement of the harbor of Karachi, India, with map. *India Engineering*, Feb. 4, et seq., 1888.

Heat and Steam, Notes on. By R. H. Buel. A series of articles for practical men, giving a collection of the most prominent data, with tables founded on the same. *Am. Engr.*, May 2, et seq., 1888.

Heating and Ventilation. Warm Air. By W. D. Snow. Discusses the uses of a forced current of warm air, and advocates the use of this method, with exhaust steam, for shop warming. *Master Mechanic*, May, 1888.

Heating Plant. Boston Heating Co. By A. P. Abbot before the Boston Society of Civil Engineers. Gives full description of the plant, the method of construction adopted in the streets and details of fixtures. *Eng. and Build. Rec.*, May 5, et seq.

Injectors and Steam Pumps, Comparative Efficiency of. Finds the relative economy and difference in amount of fuel used with a boiler fed by a pump and by an injector. *Stevens Indicator*, April 20, 1888; *Am. Eng.*, April 18, 1888.

Lamps, Maximum Efficiency of Incandescent. See Electric Light.

Locomotive, Compound Express. Gives a two-page plate showing sectional elevation and plan of a compound express locomotive built for the North-eastern Railway, Eng. *Engineering*, March 30, 1888. Details of tests of these engines in *Engineering*, April 13, 1888.

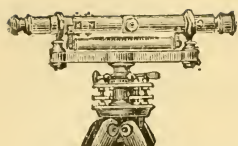
Locomotives, Draft Appliances in. A paper by F. C. Smith before the April meeting of the Western Railroad Club. Gives results of experiments made on a number of engines to see what could be done to obtain a better efficiency. Discussion. *R. R. Gazette*, April 20, 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.

——. Express. Baltimore & Ohio. Gives a brief description with two-page plate, and extracts from the specifications of a new eight-wheel locomotive built for the Baltimore & Ohio Railroad. Its dimensions are: Cylinders, 19 by 20 in.; drivers, 66 in.; boiler, 53 in.; tubes, 174; weight on drivers, 70,000 lbs.; total weight, 102,000 lbs. *Master Mechanic*, May, 1888.

——, *Light Tramway.* Gives brief illustrated description of the locomotives used on the Cavan, Leitrim and Roscommon tramway, Ireland. *Engineer*, April 20, 1888.

——, *Passenger, Caledonian Railroad.* Gives half plan, elevation and cross-section of a passenger locomotive for the Caledonian Railroad. It has two pairs 5 ft. 9 in drivers, cylinders 18 x 26 in., and weighs 83,000 lbs. *Engineer*, April 13, 1888.

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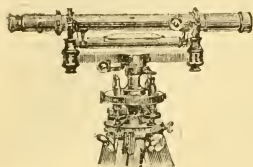
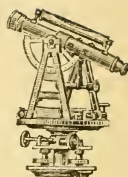
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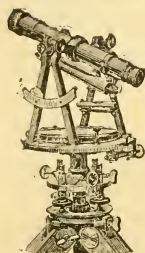
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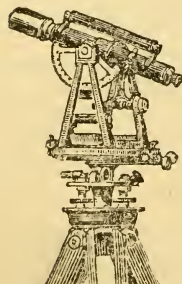
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INDEX DEPARTMENT.

- Lubricants.** By J. E. Denton. A paper before the Nashville meeting of the American Society of Mechanical Engineers, discussing the mechanical significance of the determination of viscosity. *R. R. Gazette*, May 11, 1888.
- Gives tables showing proportion of various oils commonly used for lubrication. *Engineering*, April 20, 1888.
- Meters.** See Water Meters.
- Mining Mica in North Carolina.** By Wm. B. Phillips. A series of papers describing the geology of the mining districts, formation of the veins, dressing the mica, etc. *Engin. and Min. Jour.*, April 21 *et seq.*, 1888.
- Motor, Triple Thermic.** By Chas. H. Haswell before the American Society of Civil Engineers. Gives description, operation and results of a single expansion, non-condensing steam engine, supplemented by the evaporation of bisulphide of carbon and expansion of its vapor. *Trans. Am. Soc. C. E.*, Vol. XVII., pp. 193-199, October, 1888. *Sci. Am. Supple.*, April 14, 1888.
- Oil Wells.** See Gas.
- Ordnance.** *The Zalinski Pneumatic Torpedo Gun.* Extracts from a paper by Capt. E. L. Zalinski, U. S. A., read before the U. S. Naval Institute, December, 1887, on the Naval Uses of the Pneumatic Torpedo Gun. *Railroad and Engineering Journal*, May, 1888.
- Ore Sorting.** By T. L. Bartlett. Gives a description of the method of ore sorting employed at Milan mine. *Engin. & Min. Jour.*, April 14, 1888.
- Pavements, Wood in Paris.** An abstract from a paper by M. A. Laurent in *Genie Civil* give details of the present practice of paving with wood in Paris. *Eng. & Build. Rec.*, April 7, 1888.
- Pile Trestles.** Gives detailed drawings of the standard trestle of the Chicago, Burlington & Northern Railroad. *Engin. News*, May 5, 1888.
- Propellers. Experiments with Screw.** By J. B. Andreae, before the Institute of Naval Architects. Gives details of experiments with four and two-bladed propellers. *Engineering*, April 13, 1888.
- Piping.** See Water-Works.
- Railroads, Building a Second Track.** By H. C. Thompson, before the Civil Engineers' Club of Cleveland. Discusses the question of building an additional track to a single track railroad already in operation. *Jour. Assoc. Engin. Soc.*, April, 1888.
- *Cause of Shock.* By H. Hollerith. Discusses the shock produced in stopping trains in the light of the theory of impact. *R. R. Gazette*, April 27, 1888.
- *Depreciation of Freight Cars.* Gives a table showing the value of a freight car at any age, estimated at 6 per cent. per annum as per Master Car-Builders' rules. *R. R. Gazette*, April 27, 1888.
- *Effect of rail upon wheel, and of wheel upon rail.* Review of book by Boedecker, Hanover, 1887. Hahn, publisher.
- *Interlocking Switches and Signals.* By Charles R. Johnson. A series of papers showing the progress made in the use of interlocking switches and signals, and the modifications in practice. *R. R. Gazette*, May 4, *et seq.*, 1888.
- *Maintenance of Track.* By John M. Goodwin. An attempt to show the relation existing between the cost of track maintenance and the use of steel rails. *R. R. Gazette*, May 4, 1884.
- *100 000-lb Car, Penn. R. R.* Gives drawing showing details of a car of 100,000 lbs. capacity designed for carrying cables for street railroads, and built for the Pennsylvania Railroad. *R. R. Gazette*, May 11, 1888.
- *Permanent Way.* Gives a summary of returns received in reply to circular issued under a resolution pertaining to roadway adopted at a meeting of the Association of North American Railroad Superintendents, Oct. 11, 1887. *R. R. Gazette*, April 13, 1888.
- Rails, Improved Street Car.** Describes the types of rails in use for street car traffic abroad. Illustrated. *Eng. News*, May 12, 1888.

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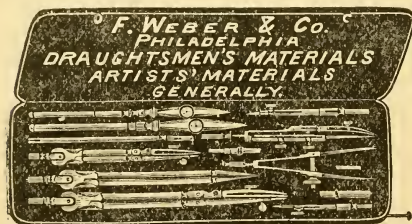
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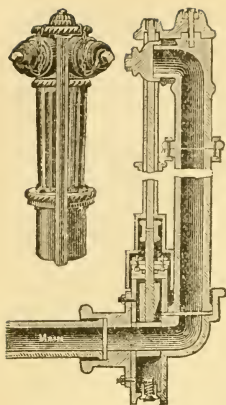
PAPERS.

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- Reservoir and Dam, Athens, Ga.** By C. H. Ledlie, before the Engineers' Club of St. Louis. Gives details of the construction of an earthen dam for the Athens, Ga., water-works. *Jour. Assoc. Eng. Soc.*, April, 1888. *Eng. News*, May 5, 1888.
- Roof-Truss, Phoenix Bridge Co.** Gives short description, with general plans, elevation diagrams and details of the roof-trusses of the new girder-shop of the Phoenix Bridge Works. *Eng. and Build. Rec.*, April 7, 1888.
- , *Carlisle Markets.* Gives a description, with double-page plates of detailed drawing, of a 70-foot span roof truss. *Engineer*, March 30, et seq., 1888.
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- Ship Transfer. Present Aspect of the Problem of American Inter-Ocean Ship Transfer.** Read before the Engineers' Club of St. Louis, March 2, 1887, by Robert Moore. A complete and interesting exposition of the subject. *Jour. Assoc. of Engr. Soc.*, February, 1888.
- , By E. L. Corthell. A review of the above paper, and a reply to the review by Robert Moore. *Jour. Assoc. of Engr. Soc.*, May, 1888.
- Standard of Length, Wave Length of Sodium as a.** By Prof. A. A. Michelson and E. W. Morly, before the Civil Engineers' Club of Cleveland. Gives a method for making the wave length of sodium light the actual and practical standard of length. *Jour. Assoc. of Engin. Soc.*, May, 1888.
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- , *New Jersey State.* An extract from the Report of the State Survey of New Jersey, describing the work done and the manner of preparing the results for publication. *Eng. News*, April 14, 1888.
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Outlet.....	57.5	65.79	0.63	678.18
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Inlet.....	71.7	73.72		
Outlet.....	48.5	56.19	17.53	667.32
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—, *Discharge of.* See Flow of Water.

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—, *Examination of in Massachusetts.* Abstract of the report of F. P. Stearns, Chief Engineer to the State Board of Health of Massachusetts for 1887. Discusses filter galleries and covered reservoirs. *Engr. and Build. Rec.*, April 14, 1888.

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—, *Hydrant Service.* A discussion on the proper charge for hydrant service in *Jour. New Eng. W. Works Assoc.*, September, 1886.

—, *Sanitary Protection of.* A paper by J. M. Tubbs, before the American Water-Works Association. Describes the method adopted for the sanitary protection of the water-shed of Hemlock Lake, supplying water to Rochester, N. Y. *Eng. News*, April 28, 1888.

—, *Treatment and Sources.* Address of President J. T. Fanning at the eighth annual meeting of the American Water-Works Association. Treats of artificial and natural clarification, deep well supplies, and the protection of sources of supply. *Engin. News*, April 28, 1888; *Engin. and Build. Rec.*, May 5, 1888.

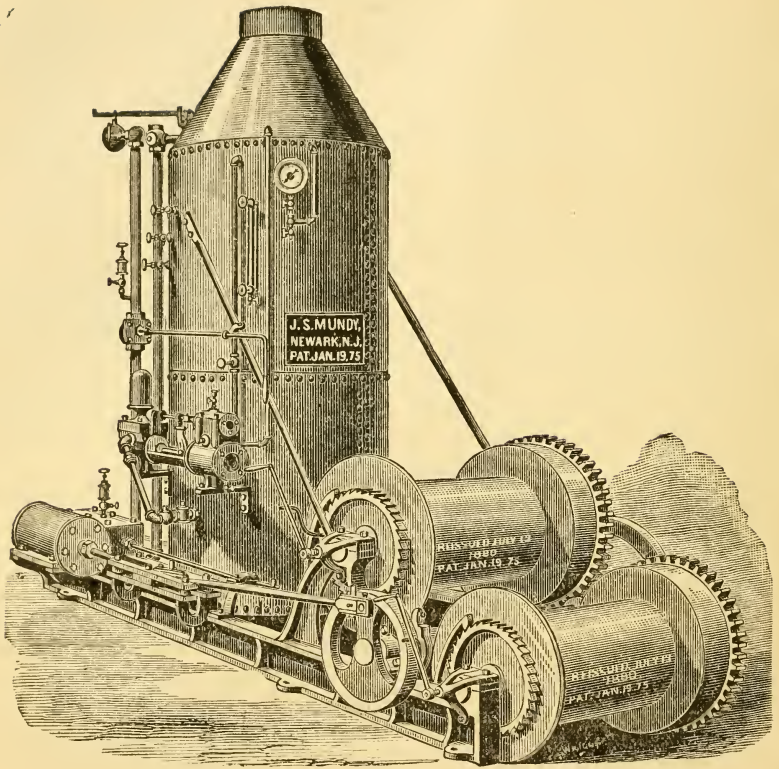
—, *Use of Vitrified Pipe in.* By S. E. Babcock, before the American Water-Works Association. Gives experience in the use of salt glazed vitrified pipe for conduit. Describes the conduit at Amsterdam and Little Falls, N. Y. Discussion contains description of a conduit of redwood. *Engin. News*, April 28, 1888.

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—, *Cleveland, O.* By J. Whitelaw, before the American Water-Works Association. Gives a short description and history of the Cleveland water-works. *Engin. and Build. Rec.*, April 28, 1888.

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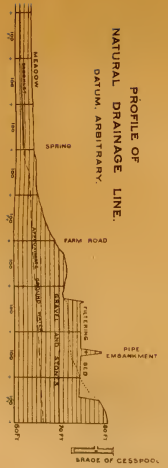
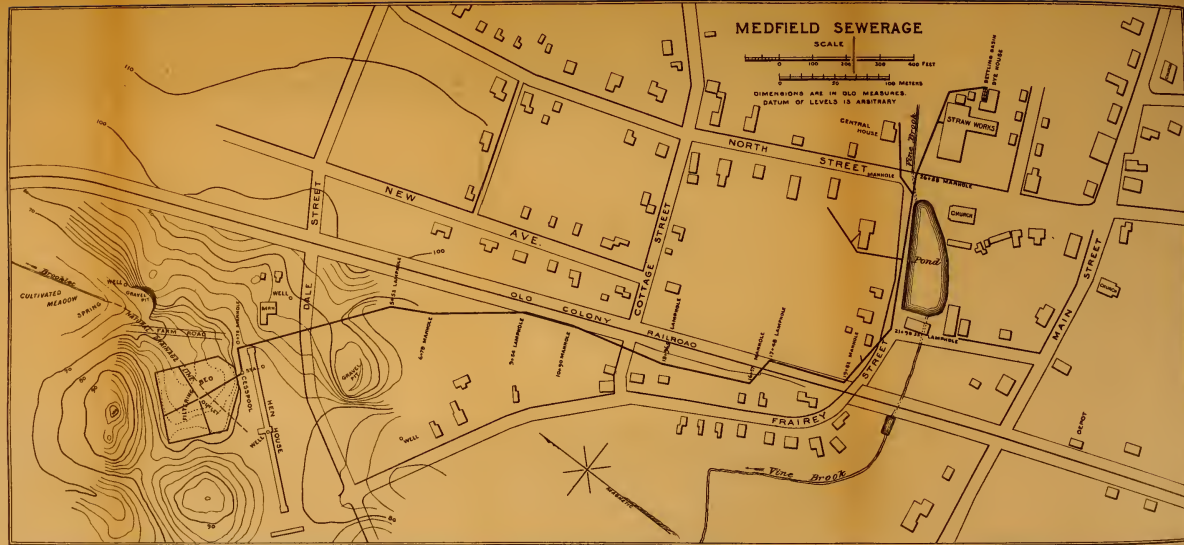
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SEWAGE DISPOSAL AT MEDFIELD, MASS.

BY FRED. BROOKS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read February 15, 1888.]

The following is a very slight modification of the account of the sewerage of Medfield, prepared by the writer and published in 1888 in the nineteenth report (for 1887) of the Massachusetts State Board of Health, to whom acknowledgment is due for facilitating the present publication.

Medfield is an old town on Charles River, seventeen miles from Boston. Its population in 1885 was 1,594; valuation, \$1,110,858; receipts and expenditures, about \$13,000 each; so that relatively to the size of the place the sewerage here described, which cost but a few thousand dollars, is comparable with the costly sewerage works of great cities. The business of Medfield is mostly agricultural, the principal exception being the Excelsior Straw Works in the middle of the town, employing in the busy season six or seven hundred operatives, but during about five months in the summer and fall, less than half as many. The general plan folded herewith (Plate I.) will enable the character of the work of sewerage to be understood with the aid of a brief description.

The straw works drainage, nearly half of which comes from the vats in which straw is dyed, used to run into Vine Brook, which flows past the works and is dammed up in a small pond just below, whose level is frequently raised and lowered for mechanical purposes. This produced an offensive smell around the pond, and blackened and polluted the water so that some residents below on both sides of the brook immediately west of the railroad track, who had used its water for domestic supply, were obliged to abandon it, and made several complaints. In 1886 a pipe sewer was built chiefly for the purpose of keeping the sewage from the straw works out of Vine Brook, and disposing of it so as to avoid the nuisance. The sewer has been entered also by the Central House (having accommodations for about forty boarders), which formerly drained into the brook, and by three private dwelling houses which did not drain into the brook. As a result the channel of the brook has already

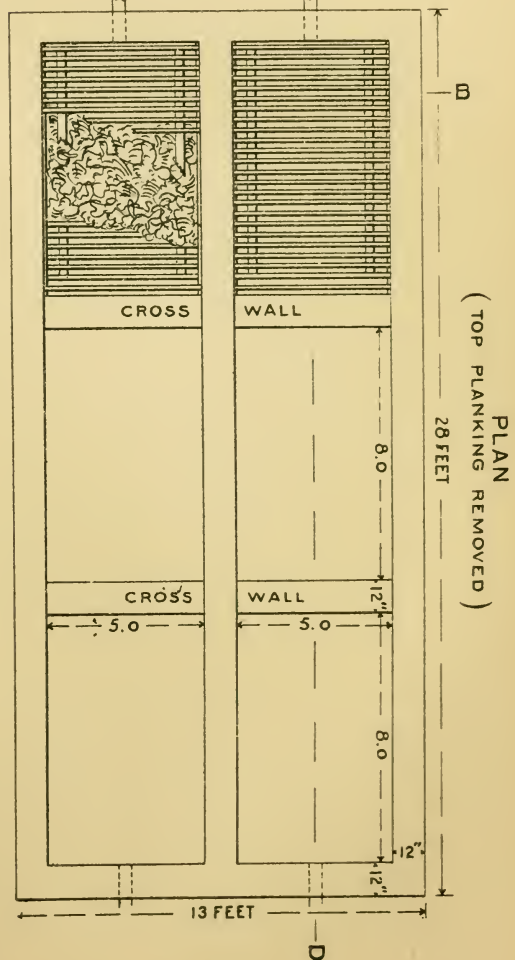
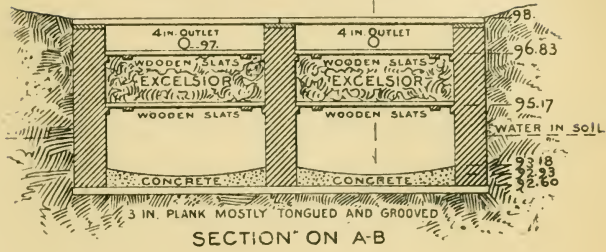
been washed so that it is inoffensive to sight and smell. A favorable place was found a little out of the village for the discharge of the sewage and its purification by intermittent downward filtration.

The work was projected by Eliot C. Clarke, C. E., and the details of its execution were put under the charge of the writer. The plans were presented to the State Board of Health in August, 1886, and were approved by the Board.

Much ground dye-wood is used at the straw works, and if this in its water-logged condition were admitted to the sewer it was not to be supposed that the sewer would be self-cleansing with the gradient available. It falls at the rate of 4 per 1,000 for nearly a quarter of a mile (400 m.). Accordingly to exclude the spent dye-wood from the sewer there was built adjacent to the dye-house a settling basin with a filter, whose construction may be understood by the aid of the accompanying drawing (Plate II.). It is made in two parts, side by side, exactly alike, in order that one-half may be in use, if necessary, while the other is being cleaned out. The discharge from the vats can be turned by a wooden gate in the trough which brings it from the dye-house into either side of the settling basin separately. Entering by the four-inch (10 cm.) openings the liquid flows generally in both sides with a total width of ten feet (3 m.) and a depth of four feet (1.2 m.) less the thickness of the deposit of sediment. The velocity of flow is thus checked, and the ground dye-wood has a chance to settle. To get into the second pair of compartments it has to pass over the brick dividing wall, whose elevation is the same as the bottom of the inlet pipe. Here is another opportunity for settlement to take place, but apparently very little collects in the second compartments until the first are pretty well filled. In the third compartments by a tight board partition the liquid is obliged to pass downward, and escape by upward filtration through a mass of excelsior held between two sets of wooden slats, as exhibited by the drawing; the upward flow being preferred, as a precaution against choking the filter. The filter was in use nearly a year before the excelsior was changed; it worked very satisfactorily, but the excelsior had by that time become so rotted that probably it would soon after have gone to pieces and escaped through the sewer. A new supply was accordingly substituted. The sediment needs to be shoveled out and carted off once or twice a year; it has a similar appearance to saw-dust, except for its black color.

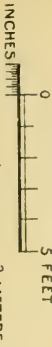
From the settling basin the sewer of Akron vitrified clay pipe runs four inches (10 cm.) in diameter to where other drainage of the straw works enters from the water-closets, sinks, bleachery, etc. There it enlarges to six inches (15 cm.), which is the diameter as far as the North street man-hole. The portion above mentioned, and also the branches to houses, were built at private expense. From the North street man-hole the main sewer was built by the town of Medfield as a common sewer, intended to admit sewage from shops and houses, but to exclude rain water entirely. It is eight inches (20 cm.) in diameter, and has capped branch pieces set at several points to admit of ready extension of sewerage through the thickly settled parts of the village, if required in the future. The sewer is low enough to do this, as it passes under Vine Brook at North street; for some distance both above and below

THE BRICK WALLS ARE CAPPED WITH PLANK UPON WHICH ARE LAID 2 IN. COVERING PLANKS.

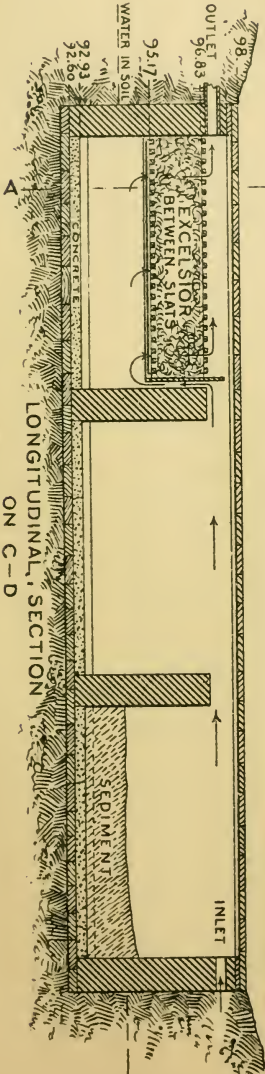


SETTLING BASIN WITH UPWARD FILTRATION.

SCALE



DIMENSIONS ARE FIGURED IN OLD MEASURES.



that point it is below the level of the water in the soil. Three lengths of pipe under the brook (thirty-six feet or eleven meters in all) are of iron, with lead joints, and are probably tight. The rest of the sewer is laid with Akron pipe, jointed with cement mortar; and although it was intended to be as tight as a bottle, it in fact admits water from the soil, both above and below the brook crossing. The quantity thus leaking in was approximately estimated, before sewage was admitted, by pumping out all that came to the North street man-hole and determining the rate of pumping by observing how long it took to fill a pail; also by measuring at the same time the depth of the water flowing in the sewer at the man-hole by the railroad bridge. It was estimated a year later by observing the minimum flow, as on holidays, when little sewage is running. The quantity appears to be about 2,000 cubic feet (57 m³) per 24 hours, and does not appear to have increased or diminished materially. This leakage is likely to continue until a portion of the Akron pipe is replaced by iron pipe.

The sewer does not fall at so rapid a rate as Vine Brook, and after passing close beside the pond the rest of the sewer is laid in dry gravel. The line of the sewer diverges more and more from the brook, and as it approaches Dale street it passes out of the water-shed of Vine Brook. It is laid in straight lines, and has a man-hole and a lamp-hole alternately at each angle.

Near the lower end of the sewer the sewage passes through a cesspool arranged as shown on the accompanying drawing (Plate III.), so that the outflow takes place from beneath the surface of the sewage standing in the cesspool. The effect is that objects which either float or sink are held back until they are sufficiently changed by chemical or other action to flow uniformly with the rest of the liquid, and are prevented from being thrown out upon the ground at the outlet, where lumps of fecal matter, orange peel, and the like might be offensive or ill-adapted for percolating through the ground. Very little sediment collects in the cesspool. The T-branch piece, however, at the cesspool outlet was not put on as required for about a year, during which time the sewage was allowed to run through without interruption of its surface; and presumably in consequence of this neglect, the outlet of the cesspool was once stopped up by some floating substance. When after this delay of a year the T-branch was set, sediment about a foot (0.3 m.) deep was found in the cesspool. To empty the cesspool for setting the T, a pump was used powerful enough to dispose of all the sewage running. This sewerage work is on so small a scale that it is possible to do without a by-pass such as would otherwise be needed to take care of the sewage flowing during any repairs or cleansing at the cesspool. In this case the sewer could be plugged up temporarily at the first man-hole, 75 feet (23 m.) from the cesspool; if the plug were at the upper side of the man-hole the sewer could fill for a few hours before overflow could take place at the first lamp-hole, 553 feet (169 m.) from the cesspool; if the plug were at the lower side of the man-hole the sewage could run out upon the ground adjacent to the filtering bed, as the man-hole is only 2 or 3 feet (0.8 m.) deep. As to ventilation, there appears to be some danger that in case the wind should blow directly into the mouth of the sewer, pressure might

be produced at the house connections, although the writer is not aware that any trouble has arisen; to obviate the supposed danger it might be well to bore a few holes in the wooden covering of the cesspool, or better to extend the upward end of the T-branch piece through it.

The average velocity of the sewage is about 1.7 feet (0.5 m.) per second, for it takes about half an hour for it to pass from the dye-house through the sewer, which is nearly 3,200 feet (1 km.) in extremelength, to the outlet, where it flows out upon the surface of the ground. This disposal of it is the principal subject of interest about the work. The filtering bed upon which the sewage is discharged consists of one acre (4,000 m.²) of ground graded nearly level. It was intended to be conical, sloping at the rate of five per thousand away from the center, where the outlet of the sewer is; but owing to slight imperfections in the work, unequal settlement, etc., it is a little irregular,—generally flatter. Material was excavated from the higher exterior portion of the site selected and filled in upon the lower portion, so as to balance the cutting and filling, as may be seen by the accompanying profile of the natural drainage line, and by the general plan, which exhibits by dotted lines the original contours of the ground. The amount of material moved was 2,000 cubic yards (1,500 m.³); the distance, very short. The shape of the filtering bed was made a little irregular to adapt it to the existing topographical conditions; but it is substantially a square, subdivided into four small squares of one-quarter acre (1,000 m.²) each by little embankments, three of which are about a foot (0.3 m.) in height; the fourth covers the pipe to a depth of three feet (0.9 m.), for protection against freezing or other injury. To prevent the sewage from running off from the filtering bed without penetrating its surface, the filling was also embanked about a foot (0.3 m.) above the graded surface along the northeast side of the filtering bed, the only portion of the exterior line where the graded surface was not lower than the ground adjacent. The material is mostly gravel and stones from the size of a man's fist downwards, and is well suited for the purpose of filtration. In grading the filtering bed the thin stratum of loam and grass upon the surface was not removed; it was simply ploughed up and then handled like the gravel. But the narrow strip under the embankment through which the pipe is laid, had its loam stripped off, and the gravel with which it was replaced was carefully puddled to make an unyielding foundation for the pipe. At the middle of the filtering bed the pipe sewer ends, as shown on Plate III., in a wooden trough having four outlets,—one to each subdivision of the filtering bed,—which outlets are closed by three gates; so that the sewage runs on to one subdivision, and is shut off from the other three. Every other day the gate is changed from one outlet to the next, so as to turn two days' sewage on to a subdivision, and then give it six days' rest, to allow the sewage to pass off through the ground, and let the surface of that division become dry enough for another dose. If such a filtering bed were so located as to be washed by the rainfall on any considerable area it might be protected by an intercepting ditch around the upper side.

No underdrainage has been put in at the filtering bed. The ground water naturally is about ten feet (3 m.) below the surface of the filtering bed. Judging from the visible indications, especially the contour of the

surface of the ground, the natural drainage from the filtering bed must be in the direction of a little depression leading down toward the meadow to the northward, where there is a spring of very good water which is the source of a permanent stream, as shown on the plan and profile. The artificially straight course of the little stream may be explained by the fact that the meadow through which it flows was graded up several years ago, so that better crops could be cultivated. This stream being a tributary of Charles River, upon whose banks a long distance below are situated the filtering galleries from which several municipalities draw their water supply, Medfield sewage requires to be purified before entering it. To determine as to the purification accomplished, chemical and biological examinations of the spring water and other water in the vicinity have been made by the State Board of Health, as shown in the tables herewith.

The samples of sewage were taken from the outlet in the middle of the filtering bed. To determine the quality of unpolluted ground water, samples were taken from several wells in the vicinity, whose positions are shown on the plan. Much the most useful one for the purpose is the one (Nos. 1,296 and 1,666) near the spring, from which it is 78 feet (24 m.) distant; the surface of the water in this well was observed to be about $1\frac{7}{8}$ feet (0.5 m.) higher than the spring. Moreover, the contour of the ground would lead one to suppose that the natural direction of percolation under ground is from the well toward the spring. There are no buildings near and the well is out of use. The spring existed before the sewerage, and has a considerable water-shed to draw from; but that some of the effluent from the filtering bed now mingles with its waters is very plain from the analyses, the first of which was made after the works had been in operation nearly nine months; the excesses, in all the analyses, of residue, chlorine and nitrates in the spring-water, as compared with the well-water, and also their variation in the different analyses of the spring-water show it. As the proportion of chlorine in the spring-water is not far from a mean between that in the well-water and that in the sewage, it may be inferred that somewhere about half of the flow from the spring comes from the sewage and about half from the soil, for it is found that chlorides pass through sand filters unchanged. The quantity of water flowing visibly from the spring appears to be less than is discharged from the sewer, so that a portion of the outflow must take place beneath the ground. The comparison of the sewage and spring-water analyses in respect to ammonia and nitrates shows not mere dilution, but purification; the free ammonia and albuminoid ammonia, found in large quantity in the sewage, represent organic nitrogenous matter; oxidation converts the nitrogen into the inorganic form of nitrates, and it is these which are found in the spring-water in very much greater proportion than in the sewage, while from the spring-water the ammonia has almost disappeared. In respect to ammonia, the spring-water compares favorably, not only with well-water, as given in this table, but with public water supplies, including many that are drawn from the ground. Neither sight, taste nor smell detects anything objectionable in the spring-water. That purification takes place in winter as well as summer is shown by the last analysis, January 23, 1888.

Spring Containing Effluent from the Filtering Bed.

	Aug. 29.	Clear.	None.	Faintly straw-like.	Very faint or none.	11.80	0.95	10.85 Peaty residue.	.0026	1.14	.195	None.	62
1295	Nov. 30.	Clear.	None.	Very faint or none.	None.	16.00	3.10	12.90 Decidedly acid.	.0024	1.63	.250	None.	62
1665	Jan. 23.	Clear.	None.	None.	Very faint or none.	15.40	2.60	12.80 Faintly acid.	.0043	1.33	.300	Present	62

No. 1034.—From well in hen-house. It had not been used since about Sept. 6, 1887, on account of failure of pump. This sample was taken immediately after repairs of pump. Disinfectant is used in the hen-house and is very conspicuous to the smell.

No. 1035.—From well near Frairey street not recently used. Half a pailful of water from another source was poured in to moisten the valves of the pump.

No. 1036.—From well near the barn.

Nos. 1296 and 1666.—From disused well near spring. Water is shallow, and it is not easy to get sample without some sediment.

No. 1033.—About twenty people in the straw works. Some vats were emptied at the dye-house at a time to contribute to this sample. Of the residue on evaporation, 8.80 parts in 100,000 were suspended matters; 57.10 parts in 100,000 were in solution.

No. 1294.—Dye-house and bleachery in full blast. About 400 people in the straw shop. Of the residue on evaporation, 10.90 parts in 100,000 were suspended matters, 79.40 parts in 100,000 were in solution.

No. 1667.—About 750 people in the straw works. Work more active than ever before.

Nos. 649, 1295 and 1665.—The temperature of the spring water, Nov. 30, 1887, was 8° C., that of the air being — 1° C.; on Jan. 31, 1888, it was 5° C., that of the air being — 3° C.

BIOLOGICAL EXAMINATION.

Samples collected Feb. 24, 1888, were tested by the method of plate culture, and the number of bacteria per cubic centimeter was estimated thus:

In water from disused well near spring.....	98
In sewage from the sewer outlet (3 samples) . . .	1,046,400 to 1,320,000
In water from the deepest part of the spring (2 samples with 21 minutes interval)	560 and 114
“ “ brooklet, 40 feet (12 m.), down stream from the spring	17,531

Surface water was running into the spring and into the brooklet along 40 feet (12 m.) of its course below the spring; this probably accounts for the difference between the two samples from the spring, and for the enormously greater number of bacteria from the brook sample. Stable manure was spread over the meadow in the fall of 1887.

The success of this filtering bed during the severe cold of winter has been favored by the fact that the dye vats are kept at a high temperature. Daily observations in October, November, December and January, 1887-88, show that the temperature of the sewage as it comes upon the filtering bed at the outlet is, while business is active at the straw works, generally from 15 degrees to 27 degrees C., falling at night and on holidays from that downward to about the temperature of the ground water, say 10 degrees C. In January, 1887, on a day when the thermometer went down to 32 degrees below zero C., the sewage was turned on to a division of the filtering bed that was covered with snow and ice. The writer visited it a few days later, and found that from a strip five or ten feet (2 or 3 m.) wide, extending nearly across the bed, the snow and ice had been melted away. The sewage had also run underneath the remaining snow and ice a little way, so that on digging with a shovel through it—say ten feet (3 m.) from this open place—moist and unfrozen ground was found beneath; still further away, the ground was frozen. On January 31, 1888, shortly after a period of severe cold, there was a large sheet of ice strong enough to walk upon, between which and the moist surface of the ground was a void space of about 0.4 foot (12 cm.) in depth, showing conclusively that after collecting in a pond the sewage had soaked away into the ground.

With regard to the quantity of liquid discharged upon the filtering bed, it was estimated in the latter part of 1887 by putting a little weir at one of the wooden trough outlets and observing at intervals the height of water going over it. It fluctuates a great deal, but it is estimated that (including a leakage of 1,000 cubic feet [23 m.³] per 12 hours of clean water, above spoken of) on 180 working days there is an average flow of 4,000 cubic feet (113 m.³) in 12 hours; on 120 working days, of 2,500 cubic feet (71 m.³) in 12 hours, and on 65 holidays and 365 nights, of 1,250 cubic feet (35 m.³) in 12 hours. That this estimate (though not claiming to be minutely accurate) is substantially correct may be judged by comparing such estimates as can be made from known facts as to the number of people in the buildings and the quantities usually discharged from the dye-house and bleachery; also by comparing the estimated quantity of water pumped from an artesian well which is the original source of most of the liquid that gets into the sewer. Most of what is pumped from this well ultimately finds its way into the sewer. More has been pumped heretofore than the required water supply, and the excess has been allowed to overflow from a tank and escape into the sewer, making just so much unnecessary hindrance to the drying of the filtering bed; whereas, if pumped at all, it might better have overflowed into Vine Brook, being pure water. For purposes of comparison the quantity of liquid discharged upon this filtering bed of one acre (4,000 square meters) may be estimated at 4,250 cubic feet (120 cubic meters) per twenty-four hours the year round, though the actual want of uniformity must make the effect rather different. For the purpose of comparison as to the population provided for, we may assume, as an approximation, that the manufacturing waste from the straw works takes the place of the domestic waste that would ordinarily go with the number of operatives that board outside of the sewered area; and thus counting operatives

and residents alike, may call the average population provided for about 500.

The works were designed for about 3,000 to 3,500 cubic feet (about 90 m.³) of sewage per twenty-four hours ; but the town secured an additional acre (4,000 m.²) of ground around the present graded filtering bed with a view to extending its area, if an increase in the quantity of sewage to be disposed of should hereafter make it necessary. At present the full area prepared is not fairly availed of, because from the neglect to grade the surface more accurately by a little harrowing there are portions which stand high and dry and have never been touched by the sewage, which collects in the low places where, after two days' discharge, it stands in a pool. The six days following hardly give sufficient opportunity for it to percolate through the soil, and for the surface of the filtering bed to become dry. The natural tendency is toward the formation of a moist, pasty coating over the surface of the lowest points of the filtering bed, entirely contrary to the intention with which it was laid out. In spite of this imperfection, which it is not to be supposed will be allowed to continue, the general working of the scheme has been highly satisfactory. No smell is noticeable except just at the outlet of the sewer. Some weeds and grass have sprung up on the higher portions of the filtering bed ; there has been no intention of cultivating it.

The work for the town was done under a contract for a "lump" sum ; the cost of the disposal works was probably about \$1,000, including cesspool, pipe from cesspool to outlet, earthwork, engineering, superintendence and profit to contractor, and the value of the land, which was given to the town. The annual expense of maintenance of the work of disposal is insignificant—probably about thirty dollars. A man has to change the gate regularly, which is the principal labor required. The surface ought to be harrowed over when it gets clogged with sediment, the embankments repaired if they get trodden down or washed, the wooden parts will have to be occasionally renewed as they decay, the cesspool will have to be emptied sometime ; but a very few days' labor annually will cover all that appears to be required.

To conclude, these works on a small scale furnish an instructive example of the feasibility of disposing of sewage upon land under favorable conditions without nuisance, with very slight annual expense, and with thorough purification of the effluent. The successful working in the winter of this sewage disposal is somewhat less valuable as a precedent for other places, because of the exceptionally high temperature of this sewage.

DISCUSSION.

Mr. F. P. Stearns : I visited the sewage disposal area of the State institutions at Cranston, R. I., on the 28th day of January, 1888. The temperature of the air in the morning was -19.4° C. (3° below zero F.), and at one P. M., at the time of the visit, -15.6° C. (4° F.). This was one of the coldest days of the season, at the end of a very cold week, and near the end of the coldest January since 1857.

The population of the institutions contributing sewage was about 1,000, and the mean flow about 90,000 gals. per day. The sewage was being turned upon a level tract of about 2.5 acres. The surface of the ground

was generally covered with ice about 5 inches thick. Near where the sewage went upon the field it was not frozen. Beyond this it appeared to be flowing over the ice, and a new layer was forming upon the surface of the sewage. To all appearances very little sewage was entering the ground. It is evident, however, either that the sewage did enter the ground, or that it had been filtering through prior to this time, as the total accumulation of ice upon the surface did not represent more than 3 days' flow of the sewage, and a large portion of it was probably due to rain and snow, the precipitation for the month having been 4.5 inches. The areas were so arranged that no sewage could run off over the surface.

The conditions prevailing at this time made this a very severe test of sewage disposal in winter, yet the results seemed to be very satisfactory, notwithstanding the apparent freezing of nearly all of the sewage on the day of the visit. There was no odor, no sewage running off unfiltered into the streams, and but little had accumulated in the form of ice.

Not only was the weather very cold, but the temperature of the sewage (4.7°C . (40.5°F .)), was unusually low. The average temperature of Med-field sewage in January, 1888, as deduced from daily observations, was 16°C . (60.7°F .). The mean temperature of sewage at the Concord Reformatory during the last week in January was 11.1°C . (51.9°F .). The mean temperature of Boston sewage during this month was 6.3°C . (43.3°F .).

SOME FACTS ABOUT THE CHEMICAL TREATMENT OF MYSTIC SEWAGE.

BY WILBUR F. LEARNED, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read February 15, 1888.]

Ten years ago the sewage of about a dozen tanneries in Woburn and Winchester drained into the streams that fed the storage reservoir which forms the domestic supply for Charlestown, Somerville, East Boston and Chelsea. Subsequently, the Boston Water Board intercepted this sewage and diverted it to Mystic Lower Lake, the head waters of Mystic River.

The large quantity of organic matter carried down by the sewer soon caused a nuisance in the neighborhood of the outlet to such an extent that the Boston Water Board purchased a level tract of land on the line of the sewer, erected an engine and pump, built tanks and ditches, with a view of abating the nuisance by subsidence. Only a small quantity of solid matter was eliminated by this process, the balance flowing back into the sewer lower down on the line and subsequently into Mystic Lower Lake.

The first set of tanks built for subsiding the sewage was 40 feet in length, 15 feet in width and $3\frac{1}{2}$ feet in depth. The interior construction consisted of partitions extending diagonally from opposite sides toward the centre, leaving a sinuous channel through the centre and giving the appearance much like that of a fish way.

This method of construction was adopted because it was thought that the angles formed by the partitions and sides would cause the agitation of the sewage to cease, and thereby large quantities of solid matter settle at those places; but as a matter of fact the velocity of the sewage in the channel was increased beyond the rate at which the suspended matter would settle, and the sewage in the angles was more or less agitated.

The second set of tanks built 3 or 4 years later than the set already referred to was 50 feet in length, 15 feet in width, and $4\frac{1}{2}$ feet in depth.

Transverse partition were built in these tanks 9 feet apart, with intervening skimming boards.

The results obtained were an improvement on the first set, but they were far from being satisfactory; and as a sequence all the partitions in both sets were removed, leaving the interior clear of obstructions excepting such posts as were required to support the covering. By this change, the velocity of the sewage in the tanks was reduced to a minimum consistent with the size of the tanks and the quantity of sewage pumped and better results were obtained. Large amounts of money have been expended during the last three or four years to clarify the sewage with a view of obtaining an admissible effluent. Mechanical filtration has been tried without success, and unique devices applied to the tanks in connection with chemical precipitation with only partial success, and at great cost. Subsequently the writer was detailed to experiment and report on a scheme of works for treating the sewage chemically.

Character of the Sewage.—The morning flow is very much diluted with ground water; between 10 and 11 o'clock A. M., and sometimes earlier, the sewage grows heavier until 2 or 3 o'clock P. M., when it reaches its maximum density, having changed in color from dirty water in the morning to brownish black in the afternoon, passing through the various shades of tan to very deep red, and thence to almost black.

The total matter, including dissolved and undissolved matter, in the morning sewage may be stated as containing 112 grains per gallon,* while the maximum amount of matter in the afternoon sewage is 540 grains per gallon.

The suspended matter amounts to 16 grains per gallon in the morning, and 128 grains per gallon in the afternoon, or an average of about 25 per cent of the total matter in the sewage. Occasionally the sewage is slightly alkaline, though generally it is neutral.

The quantity of sewage pumped at these works is about 400,000 gallons in 24 hours.

Precipitation.—The chemical reagent used for precipitation was crude sulphate of alumina of two grades, called S. cake and B. cake. The S. cake contains 3 per cent. free sulphuric acid, 18 per cent. free alumina and 40 per cent. sulphate of alumina. The B. cake contains .005 free sulphuric acid, 18 per cent. free alumina, 44 per cent. sulphate of alumina. The large quantity of free acid in the S. cake soon destroys any ironwork with which it may come in contact, and is not therefore as preferable for a precipitant as the B. cake. The amount of precipitant used in the forenoon is always less, and with better results than in the afternoon. For instance,

* The gallon referred to in this paper is the U. S. wine gallon, containing 3.7853 litres. The ton is the Massachusetts ton of 2,000 pounds, or 907.19 kilos.

a precipitant applied to the sewage between 9 and 11 o'clock A. M., at the rate of one-half ton per 1,000,000 gallons will throw down 25 per cent. of the total matter in the sewage, while two tons per 1,000,000 gallons applied to the sewage between 3 and 4 o'clock P. M. will not precipitate more than 30 per cent. of the total matter. I have seen the reagent at the rate of one ton per 1,000,000 thrown down 31 per cent. of the total matter, and with the same sewage a treatment at the rate of two tons per 1,000,000 gallons throw down only 32 per cent. of matter.

Such results seem to show that beyond certain limits the chemicals precipitate a small amount of matter.

The coarse suspended matter is easily precipitated by a moderate amount of the chemical reagent, and some of the finer particles are also thrown down, whereby the effluent is deprived of some of its color, and a corresponding portion of the offensive matter removed; besides this, there is dissolved matter which seemingly undergoes little change in the presence of the chemical reagent.

The quantity of precipitant recommended for the Mystic Sewage is 1.75 tons of crude sulphate of alumina per 1,000,000 gallons, commencing in the morning at seven o'clock with the precipitant at the rate of half a ton per 1,000,000 gallons, and increasing gradually until the amount reaches 3 tons per 1,000,000 between two and four o'clock P. M., then decreasing as the sewage becomes less dense to the rate of half a ton per 1,000,000 at midnight. With this quantity for a precipitant, it is believed that the effluent will be clear, and tolerably free of color, the suspended matter all thrown down, and as much of the dissolved matter as may be consistent with a single reagent.

Should, however, additional purification be required an increased reagent will not give better results, but if the effluent, having all the suspended matter removed, and in a state of comparative purity be run on to land of a gravelly nature, which will act as a chemical filter, a still further state of purity will be obtained.

Velocity of Treated Sewage.—One of the experiments was made with sewage clarified by subsidence, and subsequently treated, thus forming a large quantity of fine flocculent matter which required a long time for precipitation.

The velocity of the treated sewage in the precipitation tanks varied from 0.33 feet per minute to 0.70 feet per minute. In a few instances definite quantities of suspended matter in the effluent were obtained, while in other cases when the velocity was greater no results were obtained. For instance, in one case when the velocity was 0.56 feet per minute, 23 grains per gallon were obtained, and in another when the velocity was 0.37 feet per minute 16 grains per gallon were found, while in cases when the velocity was 0.70 feet per minute no results were obtained.

It should be borne in mind that the precipitation tanks were inadequate for the purpose of precipitation.

If they had been twice as long in order to give the flocculent matter ample time to precipitate, I have no doubt that a velocity of 0.50 feet per minute would have given a very fine effluent free of suspended flocculent matter.

Treatment of Crude Sewage and of Clarified Sewage.—This experi-

ment consisted in treating crude and clarified sewage with equal quantities of precipitant at different hours of the day.

The total average per cent. of matter precipitated from the crude sewage was 29 per cent., and the amount precipitated from the clarified sewage was 30 per cent.

This small difference might have been increased somewhat by a greater number of trials, but the difference will always be small when the amount of re-agent applied to the crude sewage is adequate, because it requires a large quantity of precipitant to throw down the fine particles of matter in the clarified sewage, while the same quantity applied to the crude sewage will give very nearly as good results.

Admitting a slight advantage by treating the clarified sewage when the amount of precipitate alone is considered, the advantages obtained from the crude sewage, such as compact sludge, active precipitation, etc., far exceed that of the former method.

The benefit of having a compact sludge cannot be too highly spoken of, in fact lime is frequently added as a reagent in part for this purpose and is one of the requirements in case the sludge is to be pressed.

Tanks.—When the continuous treatment of sewage is adopted for a scheme of works the precipitation tanks should be made to obtain a depth of 5 feet of treated sewage and of sufficient width to obtain a velocity not exceeding .50 feet per minute. The nearer absolute stillness is approached the more perfect the precipitation will be.

Obstructions of all kinds, such as posts, should be avoided, and the interior form a clear open channel.

Sludge Disposal.—After the supernatant water has been drained out of the tanks there remains a semi-fluid called sludge, containing in the case of Mystic sludge 85 per cent. of water. The specific gravity of the sludge is 1.017, or about 63.5 pounds per cubic foot. It is estimated that with each million gallons of Mystic sewage there will be 5,000 cubic feet of sludge. The disposal of this sludge has become one of the most important factors in connection with the chemical treatment of sewage.

In England there are seven different methods adopted for disposing of sludge: such as drying in open pits and then given or sold to farmers; second, run on to land or dug in and deposited; third, drying and burning in kilns. In short the methods used seem to be those which cause the least trouble and expense.

The most successful method has been by pressing in the "Johnson Filter Press," made especially for that purpose, whereby its bulk is lessened 80 per cent., the fluid portion of the sludge is eliminated, leaving a firm cake, which is sold to farmers at from 5 to 8 shillings per ton.

The plant required for pressing the Mystic sludge consists of an air compressor, an air accumulator, a filter press, a sludge forcing vessel, with the various piping, together with a tip truck and other conveniences for handling the pressed cake. Such a plant would cost for the amount of sludge we will handle \$3,000.

Methods of Treating Sewage.—There are two methods adopted in England for treating sewage chemically: the continuous and intermittent. The continuous method consists in treating the sewage with certain

chemicals as a precipitant, and allowing the supernatant water to flow off as fast as may be consistent with the precipitation effected.

For this treatment sufficient tank room must be provided to obtain a very slow velocity through the tanks and to give the treated sewage sufficient time to precipitate. If the sewage is treated after passing through subsiding tanks and has become more or less clarified, the flocculent matter is extremely light and remains suspended for a long time. In which case a second reagent would be advisable to weight the flocculent matter and cause rapid precipitation. Such a reagent would be lime, applied in the form of milk of lime.

When the crude sewage is treated the heavy particles of matter help to weight the finer particles of flocculent matter, and the precipitation becomes more rapid and defecation more complete.

The intermittent method consists in filling a series of tanks with treated sewage and allowing it to stand until the precipitation is complete. The tanks are then emptied and cleaned out in turn ready for fresh supply.

When sewage is treated in this way the full effect of the reagents is obtained, the effluent is clearer and in every way more satisfactory than by the continuous method.

Recommendations.—The following recommendations were made for the treatment of the Mystic sewage.

- 1st. The intermittent treatment of the sewage.
- 2d. The construction of four tanks, each capable of holding three hours' pumping.
- 3d. A sludge well into which the sludge may be drained.
- 4th. A sludge pump for raising the sludge into flumes that convey it to shallow basins until such time as pressing the sludge may become a necessity.
- 5th. A branch sewer from the present line of sewer to a pump well on the city's land.
- 6th. An engine and pump for pumping the sewage into the tanks.
- 7th. Tanks and machinery to aid the dissolving of the Cr. Sul. Al.
- 8th. Buildings, including engine house, coal shed, etc., all at an estimated cost of \$11,000.

NOTES ON EUROPEAN PRACTICE IN SEWAGE DISPOSAL.

BY CHARLES H. SWAN, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read February 15, 1888.]

Some interesting statistics relating to sewage disposal by application to land have recently been published by the authorities at Paris and Berlin, which, together with some reported English practice, throw light upon the question as to the quantity of sewage that may be applied to

given areas of land. These statistics have not been reported to the Society, and it may be well to review some of their results in connection with the consideration of sewage disposal at Medfield, Mass.

Paris.—The preliminary experiments with the soil of Gennevilliers, which is an alluvium consisting of sand and fine gravel, led to the conclusion that when used to the depth of two meters it could purify 50,000 cubic meters of sewage per hektar per annum, provided that it were properly drained and that the conditions of frequent and regular intervals of intermittence in the application of the sewage were fulfilled. Subsequent experiment and experience have shown that the best quantity of sewage to use in connection with cultivation is somewhat less than this, and that if cultivation be made subsidiary to purification a very much larger quantity may be applied. The following statistics from the report of M. A. Durand-Claye* give some particulars of this experience.

The gradual increase in the area irrigated and in the amount of sewage distributed from 1872 to 1883 are shown in the following table. This increase still continues and it is expected that sufficient land to purify the entire sewage of Paris will be under irrigation before many years.

PROGRESS OF SEWAGE IRRIGATION AT GENNEVILLIERS.

DATE.	Volume of sewage distributed.	Area irrigated.	Volume of sewage per hektar per annum.	Average depth of sewage distributed in the year.	Remarks.
	Cub. meters.	Hektars.	Cu. meters.	Meters.	
1872	1,765,621	51	34,620	3.46	
1873	7,212,928	88	81,965	8.20	
1874	7,078,529	122	58,020	5.80	
1875	5,395,011	199	27,110	2.71	
1876	10,661,224	295	36,140	3.61	
1877	11,756,949	357	32,932	3.29	
1878	10,542,855	379	27,817	2.78	
1879	10,440,091	399	26,165	2.62	Stoppage from Nov ember, 1878, to March, 1879.
1880	15,040,645	451	33,349	3.33	
1881	18,666,648	492	37,940	3.79	
1882	18,988,366	544	34,905	3.49	
1883	17,598,416	572	30,766	3.08	
Average			38,477	3.85	
Average for 1875, '76, '77, '80, '81, '82, '83			33,306	3.33	

It will be seen from the above that, after the methods of irrigation had become systematized, the annual volume of sewage distributed varied between 27,000 and 38,000 cubic meters per hektar, and that the working average was about 33,300 cubic meters per hektar per annum:

The degree of uniformity in the monthly distribution of the sewage may be gathered from the following table. Nearly half of the sewage was distributed by gravity, the remainder being pumped.

* Assainissement de la Seine. Paris. 1885.

VOLUME OF SEWAGE DISTRIBUTED MONTHLY ON THE PLAIN OF GENNEVILLIERS
DURING THE YEAR 1883.

MONTH.	Days operated.	Total volume distributed. Cubic meters.	Remarks.
January.....	5	182,973.60	No pumping; flood in Seine; rainy.
February.....	19	1,003,326.48	965,000 cu. m. used for irrigation.
March.....	15	1,136,421.00	Working reduced on account of rain.
April.....	24	2,139,077.40	Regular working.
May.....	25	2,155,628.20	" "
June.....	24	1,877,238.60	" "
July.....	25	1,827,830.20	" "
August.....	26	2,221,332.90	" "
September.....	22	1,456,583.20	" "
October.....	24	1,006,129.80	" "
November.....	25	1,573,568.40	" "
December.....	24	1,018,305.80	Pumps stopped for alterations in conduits.
Average.....	.....	1,466,534.63	

Experiments in flooding and irrigation with large quantities of sewage were regularly made at Gennevilliers for several years. They were commenced during the winter of 1880-81 on a field 1.64 hektars in area. From December 2, 1880, to April 23, 1881 (about five months), 55,117.8 cubic meters of sewage were distributed upon this lot; making 33,608.4 cubic meters per hektar, or a depth of 3.36 meters of sewage. The field was then turned over to the farmers, who raised a fine crop of beets upon it, using during the summer the usual amounts of sewage for irrigation.

Flooding was resumed November 14, 1881, and continued until March 30, 1882 (four and one-half months). The volume of sewage distributed reached 131,213 cubic meters, or 80,008 cubic meters per hektar; the amount of sewage being more than doubled. The experiment was then continued with cultivated plants, which were treated with the greatest possible quantity of sewage. For this purpose a portion of the field, 0.54 hektars, was prepared in furrows 30 cm. and ridges 60 cm. in width. The earth was slightly argillaceous, and the thickness of the soil was about 50 cm. Irrigation was commenced April 25, 1882. The results as regards culture were very satisfactory. During 1883 an amount of sewage equivalent to 113,057 cubic meters per hektar was distributed upon the lot. Irrigation took place every two or three days. There were 158 days of irrigation during 1882.

Allowing for these intervals of rest, the net rate of distribution is equivalent to 43,940 cubic meters per hektar per annum, giving sufficient area to receive a given volume of sewage with intermittent application under these conditions. The frequency of flooding during the experiment from November 14, 1881, to March 30, 1882, is not given; but assuming it to have been about the same, the net rate of distribution to provide for a given volume of sewage becomes 92,348 cubic meters per hektar per annum under this assumption. These numbers may be taken

as approximately indicating 50,000 and 100,000 cubic meters per hektar per annum respectively.

The purity of the effluent at Gennevilliers, whose clearness and brilliancy is strikingly noticeable as it issues from the drains, has been proved by numerous analyses. The amount of nitrogen, organic or ammoniacal, is extremely small, and does not amount to one milligram per liter (one part in one million). Microscopical examination of the effluent shows scarcely a dozen microbes per cubic centimeter; the water of the Vanne, containing 62; that of the Seine, at Bercy, 1,400; and the sewage 20,000 in the same volume.

Berlin.—The soil in the vicinity of Berlin is generally sandy, but is permeable only to a slight depth on account of an impervious stratum usually found at a depth of about 1.50 meters. The area prepared for irrigation is very extensive, as it has not been found practicable to apply large quantities of sewage per hektar. The area of the irrigation fields amounts to 31.8 square kilometers, divided into two groups, one of 17 sq. km. north of Berlin, and one of 14.8 sq. km. south of that city. The soil at the north irrigation fields is much heavier than at the south irrigation fields.

The effects of these different qualities of soil are shown by the averages in the following table, which gives some statistics of the irrigations during the year ending March 31, 1887.* It will be noticed that the amount of sewage distributed on the more permeable soil at a single watering is smaller, but that the total amount distributed per annum is greater, than on the heavy soil, the waterings being more frequent.

BERLIN SEWAGE IRRIGATION. 1886-87.

Locality of the sewage farm.	Amount of sewage distributed during the year.	Area now prepared for irrigation.	Average number of times the entire prepared area was irrigated during the year.	The distribution was consequently equivalent to a single irrigation over the following areas.	Average amount equivalent to a single irrigation annually per hektar.	Average depth of sewage, equivalent to a single irrigation annually.	Average rates of irrigation based on the actual area now prepared	
							per hektar per annum.	Average depth of sewage per annum.
	cu. m.	hektars.		hektars.	cu. m.	cm.	cu. m.	m.
Osdorf (south).....	14,304,699	909.54	18.66	16,975.30	842.67	8.4	15,727.40	1.573
Grasbeeren (south) .	9,324,753	570.12	12.56	7,160.61	1,311.9	13.0	16,355.77	1.636
Falkenberg (north) .	9,017,26	731.17	7.74	5,635.92	1,594.30	5.9	1,327.55	1.233
Malchow (north)....	8,566,983	970.12	7.24	7,027.17	1,219.1	12.1	8,827.21	0.883
Totals and corresponding averages. South farms	22,679,452	1,479.66	16.31	24,135.91	979.01	9.8	15,969.50	1.597
Idem. North farms.	17,584,244	1,701.99	7.45	12,683.69	1,386.43	13.9	10,331.58	1.033
Idem. General ..	41,213,696	3,181.65	11.57	36,819.00	1,119.35	11.2	12,953.55	1.295

* Bericht der Deputation für die Verwaltung der Kanalisationswerke. Berlin, 1887.

Monthly statistics of irrigations at the irrigation fields at Malchow were given in the report for 1884-85, from which the following table is compiled. It will be seen that the amount of sewage applied per hektar was tolerably uniform during the half year from June to November, inclusive, and that during the remaining half year the amount was reduced every alternate month. The large number of waterings each month is explained by the fact that the land prepared at Malchow for irrigation comprised 9.7 square kilometers. On this extensive area many local waterings can be made simultaneously. Including the overlappings of the local waterings, the entire prepared area was irrigated, on the average, 7.5 times during the year. The amount of sewage

MONTHLY STATISTICS OF IRRIGATION AT MALCHOW, 1884-85.

MONTH.	Amount of sewage distributed	Number of water- ings.	Total area of waterings.	Average area of one watering.	Average amount of one watering per hektar.	Average depth of one watering
	cu meters.		hektars.	hektars.	cu meters	cm.
April.....	480,000	191	445.48	2.3324	1,077	10.8
May.....	582,000	263	615.07	2.3387	946	9.5
June.....	606,000	225	525.30	2.3373	1,152	11.5
July.....	645,000	240	558.89	2.3287	1,154	11.5
August.....	642,000	230	535.83	2.3297	1,198	12.0
September.....	645,000	230	536.14	2.3310	1,203	12.0
October.....	675,000	228	521.75	2.3884	1,294	12.9
November.....	582,000	236	566.97	2.4024	1,027	10.3
December.....	586,000	263	651.74	2.4781	899	9.0
January.....	558,000	238	552.83	2.3223	1,009	10.1
February.....	543,000	261	608.58	2.3333	892	8.9
March.....	583,000	239	557.56	2.3329	1,046	10.5
Totals and averages..	7,127,000	2,844	6,677.14	2.3478	1,067	10.7

distributed daily averaged 19,500 cubic meters. The average amount put on each hektar of total irrigated area was 1,067 cubic meters and the average amount put on each of the 970.27 hektars of prepared area, during the year, was 7,348 cubic meters, or a total depth of 0.735 meters. The average amount of sewage put on these irrigation fields in 1886-7 was 8,827 cubic meters per hektar, or a depth of 0.883 meters.

Nearly the entire extent of the irrigation fields is underdrained with ordinary tiles. They are usually laid from 1 meter to 1.25 meters below the surface. A less depth is not considered advisable, as the danger of stoppages from fine sand and silt would be imminent, and as the purification of the effluent would be less satisfactory were the stratum of earth shallow. But this depth cannot always be attained on account of the higher position of the bottom of the effluent ditches. Of the 3181.65 hektars prepared for irrigation, 3052.40 hektars are already drained.

The annual rainfall at Berlin ranges from 45 cm. to 63 cm.; the average being 54 cm. The mean temperature is + 0.82° C. in December,

— 1.12° in January and — 0.50° in February. In February, 1865, on account of a deficient covering of snow, the frost penetrated the earth to a depth of 75 cm. Observations of the temperatures of the earth have been taken at fourteen different points and at 3 different depths, 0.50 meter, 1 meter and 3 meters. The average of these observations on the 1st and 15th of each month are given for the years 1882 to 1885 inclusive, and show that the frost did not penetrate to a depth of 50 cm. during that period; the lowest temperature reported at the depth of 50 cm. being 2.16° C. in February, 1885. The following table gives the average temperatures of the earth during 1884 and 1885 for the whole territory observed and for the 1st and 15th of each month.

AVERAGE TEMPERATURES OF THE EARTH IN 1884 AND 1885.

DATE.	1884. Depths of			1885. Depths of		
	0.5 meter.	1 meter.	3 meters.	0.5 meter.	1 meter.	3 meters.
	C°.	C°.	C°.	C°.	C°.	C°.
Jan. 1....	4.50	6.30	9.73	4.76	6.33	9.94
" 15....	4.50	5.77	8.93	3.92	5.52	9.42
Feb. 1....	6.07	6.33	8.60	2.16	4.15	8.72
" 15....	6.27	7.03	8.72	3.31	4.89	8.41
March 1....	5.06	6.39	8.66	5.07	5.72	8.16
" 15....	6.23	6.11	8.20	4.79	5.70	8.16
April 1....	7.16	7.37	8.73	6.38	6.32	8.17
" 15....	8.23	8.30	8.74	7.39	7.72	8.45
May 1....	8.21	7.90	8.82	12.63	11.09	8.95
" 15....	13.44	10.94	9.46	10.15	10.32	9.72
June 1....	13.71	12.58	10.85	14.34	12.53	10.21
" 15....	14.63	13.30	11.20	16.21	14.43	10.98
July 1....	15.54	14.16	11.68	18.14	16.01	11.97
" 15....	18.89	16.84	12.43	19.19	17.19	12.76
Aug. 1....	16.58	16.14	13.30	17.08	16.37	13.46
" 15....	18.30	16.95	13.57	17.19	16.56	13.65
Sept. 1....	16.31	16.22	14.12	14.42	14.59	13.63
" 15....	16.58	15.89	14.07	14.36	14.36	13.53
Oct. 1....	15.55	15.38	14.03	13.11	13.90	13.59
" 15....	11.70	13.37	13.82	11.69	12.42	13.23
Nov. 1....	9.30	10.98	13.08	8.92	10.51	12.51
" 15....	8.18	9.99	12.38	7.25	8.97	11.87
Dec. 1....	4.14	6.65	11.34	6.16	7.12	11.06
" 15....	7.13	7.43	10.46	3.76	6.01	10.37

The amplitudes of the oscillations in temperature are essentially similar at the depths of 0.5 and 1 meter, but at the depth of 3 meters the amplitude is much reduced by the protection afforded by the earth. The winter of 1884 was the mildest of the four reported.

The reports of the Berlin deputation contain detailed analyses of the effluents and descriptions of the appearance and color of the samples. Some specimens were clear and colorless, others were slightly yellowish or turbid, with a few flocculent particles and a slight odor. The analyses given in the following table are from the reports for 1885-86 and 1886-87. The samples selected from those reported, give the greatest and least amounts of total ammonia, and, where practicable, give analyses in cold weather and in hot weather of effluents from each type of irrigation practiced at Berlin.

ANALYSES OF EFFLUENTS FROM THE SEWAGE FARM AT OSDORF.
(Parts per 100,000)

	From the beds.				From the meadows.			
	May 1, 1885.	July 31, 1885.	Aug. 1, 1886.	Feb. 28, 1887.	Sept. 30, 1885.	Nov. 14, 1885.	Aug. 30, 1886.	Nov. 1, 1886.
Dry residue.....	82.24	64.40	83.68	88.24	84.72	75.28	89.60	91.92
Loss on ignition of the same ..	17.12	7.84	11.98	11.52	8.08	11.76	11.92	12.80
Residue after ignition.....	65.12	56.56	72.40	76.72	76.64	63.52	77.68	79.12
Potassium permanganate required.....	1.42	2.36	1.32	5.93	0.95	3.70	2.31	1.86
Ammonia.....	0.24	0.03	0.07	1.00	0.01	0.10	0.03	0.04
Organically combined ammonia.....	0.04	0.03	0.03	0.09	Traces	0.07	0.01	0.04
Nitrogen trioxide (N_2O_3).....	0.86	0.27	0.12	1.74	0.00	0.23	0.00	0.00
Nitrogen peroxide (N_2O_5).....	19.42	7.19	6.67	1.76	11.57	10.73	12.66	10.26
Sulphur trioxide (SO_3).....					4.02			
Phosphorus pentoxide (P_2O_5).....	Traces	Traces	Traces	Traces	Traces	Traces	Traces	Traces
Chlorine (Cl).....	10.92	12.07	13.29	17.48	13.78	13.71	16.38	10.01
Potassium oxide (K_2O).....					1.58			
Sodium oxide (Na_2O).....					13.80			

	From the basins.			
	Nov. 14, 1885.	Feb. 14, 1886.	June 30, 1886.	Jan. 31, 1887.
Dry residue.....	57.92	108.96	88.64	120.96
Loss on ignition of the same.....	8.32	27.02	12.92	21.98
Residue after ignition.....	49.60	81.76	75.12	99.68
Potassium permanganate required.....	3.89	17.07 (?)	2.56	5.53
Ammonia.....	0.02	1.40	0.36	1.60
Organically combined ammonia.....	0.08	0.08	0.04	0.18
Nitrogen trioxide (N_2O_3).....	0.29	1.27	0.57	1.54
Nitrogen pentoxide (N_2O_5).....	2.38	0.00	11.15	11.42
Sulphur trioxide (SO_3).....				
Phosphorus pentoxide (P_2O_5).....	Traces	Considerable	Strong traces	Traces
Chlorine (Cl).....	13.29	20.75	14.20	20.64
Potassium oxide (K_2O).....				
Sodium oxide (Na_2O).....				

Leamington.—The published reports of English practice in sewage irrigation do not enter into detail nearly as much as do the French and German reports. This is to be regretted, as examples of sewage disposal are much more numerous in England than on the Continent. The following statistics of sewage irrigation at Leamington, Doncaster and Croydon are from the Report of the Judges appointed by the Royal Agricultural Society of England to adjudicate the prizes in the Sewage Farm Competition, 1879.* Two prizes, each of the value of one hundred pounds, were offered for the best-managed sewage farms in England and Wales. One prize was for the best managed sewage farm utilizing the sewage of not more than 20,000 people; the other was for the best managed sewage farm utilizing the sewage of more than 20,000 people.

The sewage farm at Leamington comprises 764 acres, 0 roods, 31 p. The population contributing sewage is 23,000, being 30 persons per acre of whole area of farm, or 142 persons per acre actually irrigated. It has

* *Journal of the Royal Agricultural Society of England*, 1880.

probably a larger area in proportion to population than any other sewage farm in England. The prize for sewage farms dealing with the sewage of more than 20,000 people was awarded to this farm.

"In the year 1878, 161 a. 0 r. 10 p. of land were irrigated with sewage; the average quantity of sewage applied in this year having been 5,553 tons per acre, or equivalent to an irrigation depth of 55 inches on every acre irrigated. The volume, however, given to different crops varies. In the case of rye-grass, as much as 11,912 tons per acre have been applied, which is equivalent to an irrigation depth of 117.8 inches; mangolds 8,265 tons per acre, which is equivalent to an irrigated depth of 81.83 inches; while upon land on which potatoes and savoys have been grown only 2,275 tons per acre have been applied, or an irrigated depth of 22½ inches. The soil of the farm varies in character. The greater portion, however, is very light land upon a gravel subsoil, but some portions are clay. * * * As far as possible all the solids of the sewage are pumped with the liquid. * * * The land is mostly drained, the stiff land at a depth of 4 feet, with the drains 40 feet apart, and the light land 5 feet deep, with the drains 60 feet apart. There was no surface effluent from the farm, and very little effluent from the land drains at the time of our inspections, compared with the volume of sewage which is applied to the land. * * * The prejudice which still exists in many parts of England against milk, rye-grass and vegetables grown by sewage have here all been overcome, if they ever existed, and in all seasons there are customers for all that is grown. * * * The farm was very clean, and in a good state of cultivation. * * * Twenty-six persons reside on the sewage farm, including fourteen children, and twenty others are employed who do not reside on it. At no time has there been any form of epidemic disease."

Doncaster.—The sewage farm at this place was awarded a second prize in the class of towns having a greater population than 20,000. "The farm contains an area of 304 a. 3 r. 11 p., of which 229 a. 1 r. 27 p. were irrigated in 1878, 75 a. 1 r. 24 p. not being irrigated. It was established in 1873, and receives the sewage of a population of 21,000 persons (being 69 persons per acre of whole area of farm, or 92 per acre actually irrigated). * * * At the sewage works there are fixed in the sewers cages which form screens to keep out the larger solid matters from the pumps, all the rest of the sewage being pumped on to the farm. * * * The soil is of a somewhat variable character. The larger portion of the farm is very light land, resting upon a subsoil of red sand, the remaining portion consisting of red stratified clay. * * * The light land is of an extremely porous character. * * * About 90 acres of the farm have been underdrained. In the porous soils, the drains are 6 feet deep; on the loamy soils, 4 feet 6 inches deep; and in the clay lands they are 4 feet deep. The drains vary in distance from 11 yards to 40 yards apart. Notwithstanding the large quantities of sewage which were poured upon the surface at all periods of our inspection, it was found that there was no surface effluent, and that the under drains also yielded little or no effluent water. * * * The quantity of sewage pumped on to the farm in 1878 was 921,440½ tons [equivalent to 4,016 tons per acre irrigated]. The volume of sewage applied to

various crops differs enormously. As much as 17,505 tons per acre were applied in 1878 to rye-grass, which is equivalent to a vertical irrigation depth of 173 inches in the year. Mangolds received 6,455 tons, or 64 inches, in vertical depth, and permanent grass 4,504 tons per acre, or 44 inches in depth. * * * The sewage is applied to various crops in the spring and summer, and also to a few crops in the winter; but it is largely applied to fallow land in the winter time. * * * The land is well tilled, fairly cleaned and a large quantity of produce is raised from a naturally poor soil. * * * There has been no form of epidemic disease amongst the men or their families, and no deaths have occurred on the farm."

Croydon.—"At Croydon (Beddington), sewage irrigation as a mode of purifying sewage has been practiced for a longer period than in any other town in England. * * * At the present time the farm contains 445 a. 2 r. 23 p. Not more than 330 acres of the whole farm are at present under sewage irrigation at any time. Having regard to the fact that certain crops (such as oats) are not irrigated during their period of growth, the area of land to which the sewage is actually applied does not exceed 320 acres all the year round. The population of the district draining on to this farm is estimated at 55,000, so that the sewage of at least 170 persons is constantly applied to each acre of land irrigated in the course of a year. The quantity of sewage applied in twelve months, from October, 1878, to September, 1879, was equal to a daily volume of 140 (imperial) gallons per head per day of the population. * * * Previous to the liquid sewage passing on to the land, it is passed through Mr. Baldwin Latham's patent sewage extractors, which remove the sand, solid fæces, paper, etc. * * * In the twelve months from October, 1878, to the end of September, 1879, 12,557,790 tons of sewage were passed on to the farm from both outfall sewers, an amount equivalent to a depth of 388.5 inches on the 320 acres actually irrigated [39,243 tons per acre per annum], in addition to the local rainfall, which was 33.4 inches during the same period—the actual quantity of sewage applied per acre at Croydon being seven times greater than that applied at Leamington during the same period. * * * It is a light soil, resting on a gravel subsoil. The farm is admirably adapted for irrigation, both from the character of its soil and the gradient of its slopes. * * * The farm is not drained to any great extent, and it is more or less water-logged, and it would be greatly improved both by surface and subsoil drainage; but what is urgently required is the removal of the large and increasing volume of the subsoil water from the sewers. Notwithstanding the enormous volume of sewage which is poured on to this land, the effluent flowing off at all periods of our inspection was clear and limpid."

The amount of sewage here reported seems excessive when compared with other cases. The water-logged condition of the soil also indicates an excess of sewage. It is to be regretted that no analyses were given by the judges, to show the degree of purification attained.

Medfield, Mass.—The amount of sewage distributed at Medfield is estimated by Mr. Brooks at 4,250 cubic feet every 24 hours the year

round. As the area of the filter bed is one acre, this is also the yearly average per acre per day, and is equal to 108,543 cubic meters per hektar per annum. This result agrees very closely with the result of the Paris experiment on filtration without cultivation.

SUMMARY.

The preceding statistics, which by no means include all that might be mentioned, may serve to point out, in a general way, the amount of sewage which may be disposed of under conditions analogous to those obtaining in the several cases mentioned.

The following table gives a summary of the results, reduced to uniform measures:

STATISTICS OF SEWAGE IRRIGATION AND FILTRATION.

LOCALITY.	Nature of the earth.	Remarks.	Date.	Volume of sewage.			Average depth of sewage per annum.	
				Per hektar per annum.	Per acre per annum.	Per acre per day (yearly average).		
				Cu. meters.	Tons.	Cu. feet.	Meters.	Feet.
Berlin. Malchow	Heavy.	Irrigation.	1884-85	7,348	2,925	288	0.735	2.41
Doncaster.....	Sand or gravel.	"	1886-7	8,827	3,514	346	0.883	2.90
			1878	10,989	4,916	395	1.009	3.31
Berlin. Falkenberg...	Heavy.	"	1886-7	12,327	4,907	483	1.233	4.04
Leamington.	Mostly gravel.	"	1878	13,949	5,553	546	1.395	4.58
Berlin. Osdorf.	Sandy.	"	1886-7	15,727	6,261	616	1.573	5.16
Berlin. Grossbeeren..	"	"	1886-7	16,355	6,511	640	1.656	5.37
Paris. Gennevilliers..	Sand and gravel.	{ Market garden- ing (working average).	1875-83	33,300	13,270	1,305	3.330	10.94
" "	do.	Filtration and cultivation.	1883	48,940	19,483	1,916	4.894	16.06
" "	do.	From experiments	Early	50,000	19,905	1,958	5.000	16.40
" "	do.	Filtration without cultivation.	1881-82	92,348	36,763	3,616	9.257	30.30
Croydon. Beddington	Gravel.	Broad irrigation.	1878-9	98,578	39,243*	3,860	9.858	32.34
Paris.....	Sand and gravel.	Maximum limit adopted.	1884	100,000	39,809	3,915	10.000	32.81
Medfield, Mass	Gravel.	Filtration without cultivation.	1887	108,543	43,209	4,250	10.854	35.61

* Apparently excessive.

It is seen from the above that the amount of sewage usually applied to land varies from 10,000 to 20,000 cubic meters per hektar per annum, falling nearly to 7,000 on heavy soil and rising to 33,000 with market gardening on a porous soil. That with 50,000 cubic meters per hektar per annum, the process becomes mainly one of filtration. That filtration has been continued with satisfactory results up to 100,000 cubic meters per hektar per annum, which is the maximum mentioned at Paris, and is a mean between the experiments at Paris and Medfield. These conclusions may be still further generalized by placing the amount to be used in market gardening at three times that used in ordinary irrigation, and the maximum for filtration at three times the amount for market gardening.

SELECTION, INSPECTION AND USE OF CEMENT AND MORTAR.

BY S. F. BURNETT, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 21, 1888.]

In this paper I shall endeavor to give a few practical hints in regard to the selection, inspection and action of cement and sand and the methods of mixing and using to produce a good mortar. As cement is the most important of these items I will consider it first. To obtain a good cement, what shall we specify for it and how shall we inspect it? The following conditions should be specified for it. It shall be of the very best grades of hydraulic cement, to be finely ground and put up in well-made casks and stamped with the maker's brand. It shall be subject to inspection and rigorous tests, and if found to be of improper quality it must be immediately removed from the work. Louisville cement shall stand a tension test of 90 pounds to the square inch, when allowed to set two hours in air and 48 hours in water. Portland cement shall stand a tension test of 300 pounds to the square inch, when allowed to set 24 hours in air and seven days in water. When stored, the cement shall be kept secure from moisture and currents of air.

The result of the test would be more satisfactory if the cement was given a longer time in water, but the difficulty of a long test is keeping cement enough on hand to last so long ahead.

It is almost impossible to make a contractor provide a shelter for cement that is any way secure from damp currents of air, moisture from the ground, and even rain. Hence a cement that is very good when tested may be poor by the time it is used, if too long a time is taken for testing.

Methods of Inspecting and Testing Cement.—It is often tested at the mill, where it is made as it is put up in barrels, but I very much prefer testing it on the ground where it is to be used. The simplest method of inspecting cement, and one that I have found to work nearly every time, is simply by examining the barrels. If the barrels are new and clean, without any marks on them, and the brand is one that you are familiar with, and know to be good; then it is pretty safe to say the cement is good. On the other hand, if the barrels are old and dingy, with holes plugged up in the ends of some of them, and marks on many of them, or if the barrels are old and the heads new, or newly scraped and newly branded; then beware of the cement, and do not let any of it be used until you have given it a full and rigorous test. Where the barrels are new and clean, and of a good brand, I would not be afraid to let the cement be used at once if I was in a hurry for it; but the regular modes of testing should be gone through with before the cement is used, if the time is not too pressing. This inspection of barrels applies only to Louisville cement. Nothing can be told from the barrels of Portland cement, nor from the brand either, as they vary so much.

This preliminary inspection of the barrels, etc., I consider very important, as it tells you just how to proceed with the tests that are to follow. We like to get a cement that is either very good or very bad. It is quite

aggravating to get a cement that comes up to the lowest limit allowed and no more. After one has tested cement for some time, it is a very simple thing to make five or ten pounds difference either way, at will, in the method of mixing. In most cases, the object in testing cement is not to get at the actual strength of the cement when properly mixed, but to find out if it will come up to the standard as specified, when mixed under its worst conditions. Then if you have a cement that you think is not very good, mix it accordingly, and if it then stands the test, it is safe to accept it, and if it does not stand the test, it is easy to reject it, as you have your record of what it stood.

In most cases the cement should be mixed as nearly to the same consistency and worked as nearly the same length of time as possible. The cement should be mixed to about the same consistency of the mortar for which it is to be used; it should be well worked for about a quarter of a minute. Very little more water added with less working will diminish its strength considerably. The following is a case showing about the extreme difference that can be made in the method of mixing. Sample of Louisville cement, Queen City Star brand; first sample was mixed very dry, or stiff, and pressed into the moulds, the second sample was mixed to ordinary consistency, and third sample was mixed very wet. All were allowed to stand ten days in air. The dry sample broke at 420 pounds; the ordinary one at 276 pounds, and the wet one at 115 pounds. The weights of these samples were 19, 18 and $15\frac{1}{2}$, respectively, thus showing that the more cement in the section the stronger will be the section, other things being equal. With Portland cement the method of mixing does not make nearly so much difference. Portland cement will reject nearly all surplus water.

From the above experiment it will be seen how easy it is to make five or ten pounds difference at will. It is very necessary to have the moulds of exact shape, and great care should be taken in making the briquette; it should not be removed from the mould until it is hard and perfectly rigid. This care is necessary to insure a perfectly shaped briquette; if the briquette is not perfectly shaped the amount of its tension test will be considerably less. The cause of this is twisting in the clamps, pulling more on one side than on the other, or having too great a pressure near the edges of the briquette, causing the edges to chip off and thus causing the machine to jerk.

This method of testing *neat* cement, although about the best there is, is rather unsatisfactory, as the cement that is the strongest when mixed neat, is not always the strongest when mixed with sand. For instance, take any good cement and sift it through a No. 60 sieve. In nearly every case this sifted cement, when mixed neat, will not be as strong as the original unsifted cement mixed neat; but when each is mixed with one or two parts of sand, the sample having the sifted cement in it will invariably be the stronger. The following are a few cases to illustrate: Sample of fern leaf cement stood a test of 225 pounds, setting thirty days in air. This cement sifted through a No. 60 sieve, 75 per cent. passing through. Sifted cement stood a tension test of 217 pounds, setting thirty days in air; eight pounds less than original cement. Original cement, when mixed with two of sand, stood 33 pounds. Sifted cement, when

mixed with two of sand, stood 37 pounds. When mixed with one of sand the original stood 79 pounds and sifted 120 pounds, all setting thirty days in air. Another example: Queen City Star, setting two months in air, stood a tension test of 363 pounds. Sifted through No. 60 sieve, coarse stuff ground so as to all pass through, setting three months, stood 327 pounds. This cement then sifted through No. 130 sieve, coarse stuff being rejected, setting three months, stood 295 pounds. Original cement, with one of sand, stood 125 pounds. Sifted through No. 60 sieve, with one of sand, stood 126 pounds. Sifted through No. 130 sieve, with one of sand, stood 182 pounds, all setting three months in air.

From these experiments it appears that it is very desirable to have a finely ground cement, or more properly a cement with very little coarse stuff in it. This coarse stuff seems to be neither sand nor cement. It has no cementing power in its coarse state, but if ground it makes a poor cement. When present in cement in small quantities it acts about the same as a good sand. Consequently if it was not in the cement, just that much more sand could be added, and produce an equivalent mortar. The following is an example showing the action of this coarse material compared with sand. Queen City Star cement setting two hours in air and 48 hours in water stood a tension test of 129 pounds. This cement sifted through a No. 60 sieve, 81 per cent. passing through and 19 per cent. rejected; 19 per cent. of sand was then added to the fine portion and tested. It stood 125 pounds with the same time of setting. I then tried adding 19 per cent. of sand to the original cement. It stood only 92 pounds with same time of setting. The original cement with two of sand stood 56 pounds; the sifted cement with two of sand stood 80 pounds; both setting three months in air. This coarse material is a light substance, much lighter than the cement. It is probably ashes and the part of the stone from which the cement was made, that was not adapted to making cement. Portland cements contain very little of this material. Some of this coarse stuff from an excellent Queen City Star cement was ground, and passed through a No. 100 sieve, set three months, and stood 80 pounds. Original cement, setting 36 hours, stood 95.

Slow and Quick Setting Cements.—A slow setting cement generally becomes stronger in the end than a quick setting cement. They are much easier to use and for most work preferable. About the best cement ever tested by myself took sixteen hours setting before it was hard enough to remove from the mould. This cement, setting sixteen hours in air and twenty-four hours in water, stood 367 pounds. Same cement, setting sixteen hours in air and forty-eight in water, stood 451 pounds. A third sample of same cement setting thirty days in air stood 554 pounds. A sample of Indiana blue stone, with $\frac{1}{4}$ of the section stone and $\frac{1}{2}$ Portland cement, stood 560 pounds, only six pounds more than cement. Adding a very small quantity of sugar to cement retards the setting of it very much. A cement that will set in ten or fifteen minutes with pure water will take an hour to set if a little sugar be added to the water. Whether this increases the strength of the cement or not in the end I am not prepared to say. I am inclined to think that it does. I know it is weaker after setting eight days. But this is no reason why it should not be stronger after a month. If the sugar does not act chemi-

cally on the cement, then its mechanical action, by retarding the setting, should increase its strength.

From the foregoing we will assume that we can get a good cement. Having a good cement we will not get a good mortar unless we have a good sand and the two are properly mixed and worked with the proper amount of water. The sand is much easier tested than the cement. Its quality can always be determined by its looks, feel, etc. The sand should be clean and sharp (I do not think necessarily coarse, although it is generally so required). Both sharpness and cleanliness may be tested by taking a handful of the sand, in its moist state as it comes from the barge, and pressing it together with the fingers. If the sand is good it will not stick together but immediately fall apart when the pressure is relieved. If it sticks together it is probably loamy or dirty, and is not good. Sand may also be tested by crushing a handful near the ear; if it is clean and sharp it will have a grating sound. It may be further tested for cleanliness by washing a little in the palm of the hand; the hand should be left clean. It is almost as necessary to have a good sand as it is to have a good cement. The effect of poor sand is shown by the following, using the same cement and different sands: One of cement and two of good sand setting four months stood 73 pounds. One of cement and two of poor sand setting same time stood 60 pounds. One of cement and one of good sand setting four months stood 115 pounds. One of cement and one of poor sand setting four months stood 72 pounds.

Now, having a good cement and a good sand, it is still necessary to use much care in the mixing and using to get a good mortar. The water is also of some importance; it should be free from grease. In making mortar the sand and cement should always be measured, either in barrels or some other vessels, and not by the shovelful, as most mortar men want to measure it. An excellent method for measuring the sand is as follows: Knock both ends out of a cement barrel and cut it crosswise through the middle; set the half barrels in the mortar box, big end down, and fill them with sand; lift them off of the sand, and repeat the operation until enough sand is in the box for a barrel of cement. Then dump in a barrel of cement. The sand and cement must be thoroughly mixed while dry, until the whole mass is free from spots of cement or sand, and is of an even color throughout. The dry mixture is then shoveled to one end of the box, and water poured in the other end. The sand and cement is drawn down with a hoe, small quantities at a time, and well mixed with the water, until enough has been added to make a good stiff mortar. This should be vigorously worked with a hoe for several minutes, to insure a good mixture. The mortar should then leave the hoe or trowel clean when drawn out of it; very little should stick to the steel.

This mortar should then be used as quickly as possible. The consistency of the mortar depends somewhat on the kind of work on which it is to be used, and on the state of the atmosphere. For a material that absorbs very little water, such as granite, a stiff mortar should be used; for a material that absorbs much water, such as brick, a thinner mortar should be used. In cool, damp weather a stiff mortar should be used.

When a stone or brick is once well set in mortar (say for half an hour) it should not be disturbed ; if it is necessary to move it, no matter how little, it should be taken up, the old bed of mortar scraped up and thrown away, not remixed and relaid, and a new bed of mortar laid.

In making mortar the amount mixed at a time depends on the rapidity with which it is used. It is very important that it should not be mixed faster than it is used ; any mortar that has been mixed one hour is almost worthless. Using Louisville cement, the following are examples to illustrate: Fresh mortar setting three months stood a test of 60 pounds. Same mortar remixed after standing one hour, setting three months, stood only 33 pounds, 27 pounds less. Another case of fresh mortar setting four months stood 62 lbs. This mortar remixed after standing one hour setting four months stood 40 pounds, 22 pounds less. With a Portland cement, which is generally much slower setting, the mortar can be kept longer : but I think the sooner it is used after being well mixed and worked, the better the result. A cement mortar made of one of Louisville cement and two of good sand, should stand a tension test of not less than 50 pounds to the square inch when setting three months in the air. This is very low compared with some accounts of mortar made of German and English Portland cements with three of sand. A table published by Erskine W. Fisher, of New York, of German cements, the average of nine samples of different brands with three parts of sand, setting one month was 365 pounds. But we get no such cement or mortar here. The cement mortar used on the granite work of the new stand-pipe of this city averaged 64 pounds, setting four months. This average was of 16 samples taken out of the mortar box from which it was being used on different days. This is about as good mortar as is generally used. So much for the quality and strength of cement mortar.

Effects of Freezing.—In my experience I have found that freezing of mortar before it is well set always weakens it, at least. A mortar laid in freezing weather may turn out very good; but I do not think it is ever as good as it would have been had it been laid in warmer weather. If a mortar has a few hours to set before freezing (say during the day and freeze at night) the effect is not nearly so bad as if it should freeze as soon as laid. Again, if the mortar freezes as soon as laid or shortly after, and then remains frozen for several days (until it has dried) the effect is not so bad as it would be should it thaw within one or two days after freezing. The following are some experiments showing the effect of freezing. Sample of Queen City Star cement, mixed neat and setting in moderate temperature stood 421 pounds. Same cement allowed to set 15 minutes, and then frozen and kept frozen several days, stood 290 pounds. Same cement frozen as soon as mixed, and kept frozen several days stood 260 pounds. Same cement frozen as soon as mixed and thawed out next day, stood 88 pounds. All these samples set 2½ months in air. Sample of Black Diamond cement setting without freezing, stood 410 pounds. Frozen as soon as mixed, and left exposed to weather, stood 121 pounds. Frozen after setting 15 minutes, and left exposed to weather, stood 163 pounds. Frozen after setting 30 minutes, and left exposed to weather, stood 197 pounds. One of this cement, and two of sand, set without freezing, stood 142 pounds. One of this cement, and

two of sand, frozen after setting 1 hour, stood 65 pounds. From these experiments it appears that freezing of mortar before it is perfectly set, can do nothing but injure it.

Expansion and Shrinkage of Mortar.—The question has been asked several times; "Does mortar shrink or expand while setting?" I made a number of experiments to find out, and the result of my experiments is that I think it does neither to any appreciable extent. Mortar does swell, however, when immersed in water after it has set. This I proved beyond a doubt by filling a number of lamp chimneys with different mixtures of mortar, making duplicates of each mixture. After the mortar was well set I immersed one of each kind in water, leaving the other in air. In every case the ones immersed in water began to crack, some of them within one or two days after immersing, while others did not crack for one or two months. Most of them cracked all over, cross ways and every other way, so that some of them became a perfect network of cracks. A few of them had only one or two long cracks from one end to the other; these were the ones that cracked last. All the glass remained in place as long as the chimneys were kept in water, but when they were taken out and the mortar allowed to dry, nearly all the glass fell off; thus tending to show that the mortar shrunk back to its original size. In no case did the chimneys crack while left in air. Some of these, after setting four or five months in air, I put in water. They began to crack in the same manner as the others. This swelling seems to be somewhat similar to the swelling of wood when it becomes wet.

In no case did the mortar show any sign of shrinking before it had been immersed in water, or after being immersed in water, but only after it had been taken out it appeared to shrink back to its original size.

All statements made in this paper are based on the results of actual experiments. At least ten experiments of each kind were made and a conclusion drawn from the average of the results. The experiments given in this paper as illustrations are all average experiments.

I will end here my discussion of cement and cement mortar.

I will say only a few words in regard to lime mortar.

In the first place live mortar is a rather uncertain mixture. Limes differ about as much in quality and strength as cements, and have the disadvantage that they cannot be tested as cements, except by appearance; and a big disadvantage of lime is that too little sand added is almost as bad as too much. More or less sand than the proper amount will weaken the mortar. So unlike cement mortar it cannot be made safe by adding less sand. Again, this proper amount of sand can only be determined by the appearance and working of the mortar. Hence lime mortar is very uncertain unless made by a trustworthy and thoroughly practical mortar man.

The lime used should be fresh and in compact lumps, free from much dust of air-slacked lime. These lumps must be thoroughly slacked with water before being mixed with sand. The lime should be left in a moist state for several days at least, to insure a thorough slacking before adding the sand. It is claimed by some authorities that the longer the lime stays in this moist state the better.

Sand and water is added to and worked with this moist mass of slacked lime to make a mortar of the proper consistency; this should be vigorously worked with a hoe. When properly mixed and worked it should leave the hoe or trowel clean when drawn out of it. It is just as important to have a good sand as it is with cement mortar. Lime mortar, when everything about it is first-class, makes an excellent mortar, but it requires such care and skill to make all conditions first-class that it is seldom that a very good lime mortar is obtained.

BOSTON SOCIETY OF CIVIL ENGINEERS.

REPORT OF COMMITTEE ON WEIGHTS AND MEASURES,
COMPRISING A CANVASS OF THE SOCIETY REGARDING METRIC REFORM, WITH
OPINIONS OF MEMBERS AND A NOTICE OF THE RECENT ACT OF CONGRESS.

[PRESENTED MARCH 21, 1888.]

To the Boston Society of Civil Engineers :

Your Committee on Weights and Measures was directed by vote of the Society at its regular meeting, Nov. 16, 1887, to make a canvass of the Society for the purpose of eliciting opinions regarding weights and measures, and of facilitating the expression of some response to the request of the Western Association of Architects (through their Committee on the Metric System), that this Society unite with them in petitioning Congress that the metric system be adopted by all the Departments of the Government for all Government business.

Your Committee has made the following analysis of the replies :

Questions.	Affirmative....	Negative.....	Doubtful.....	Total number of answers ..	Percentage of affirmative answers.....
(A). Whether it would be worth while ultimately to abandon many customary units, to secure uniformity and system in place of the existing irregularity ?.....	79	2	.....	81	98
(B). Whether the uniform system of the United States ought ultimately to be as exclusively decimal in its ratios between units of the same class, as United States money is now ?....	73	8	.....	81	90
(C). If the United States and foreign nations would all adopt the same system, whether the advantage to the United States over that of an equally good system peculiar to itself would be great enough to justify the United States in incurring a considerable increase of trouble and expense ?.....	68	9	2	79	86
(D). Is the ultimate exclusive adoption of the metric system throughout the United States desirable ?.....	57	19	4	80	71
(E). As to the Boston Society of Civil Engineers, as a body, joining with the Western Association of Architects in a petition to Congress, as proposed by them, for the adoption of the metric system of weights and measures by the Departments of the United States Government ?.....	49	30	2	81	60
(F). Further opinions on weights and measures ? .....	.....	.....	.....	.....	.....

Replies have been received from 83 members, or about 42 per cent. of the entire membership, which numbered 196 when the circulars were sent out. In some instances the replies did not contain answers to all of the questions.

The replies to question (F) are numerous, but are too diverse in character to admit of brief classification. They are valuable and worthy of consideration. Some of them are quite lengthy. All the replies have been deposited with the Secretary, and can be seen by any Member who may wish to examine them.

It appears to your Committee that this canvass should be interpreted on the basis of Articles XXI. and XXII. of the Constitution, which provide that no proposition which includes the Society's endorsement shall be passed except by a two-thirds vote passed in its favor at each of two successive regular meetings; or by the assent, in writing, of two-thirds of the whole number of immediate Members signified to the Secretary within one month preceding a regular meeting, and announced and recorded by him at that meeting.

Returns have been received from less than one-half of the membership, and it is therefore impracticable to draw absolute conclusions from these answers. It appears, however, to your Committee that, inasmuch as questions (A), (B), (C) and (D) have been answered affirmatively by more than two-thirds of those voting, they might receive the indorsement of the Society should formal action be taken; but that question (E), having been answered affirmatively by less than two-thirds of those voting, would not be likely to receive the indorsement of the Society.

Your Committee therefore concludes that it is not the wish of this society to unite as a body with the Western Association of Architects in a petition to Congress, as proposed by them, for the adoption of the metric system of weights and measures by the Departments of the United States Government.

Respectfully submitted,

CHARLES H. SWAN,
CHARLES W. KETTELL, } Committee.
CHARLES W. FOLSOM, }

BOSTON, March 20, 1888.

SUPPLEMENTARY REPORT—THE RECENT ACT OF CONGRESS.

Since the presentation of the Committee's report, Congress has made an enactment (approved by the President, May 24, 1888) which is likely to be decisive as to the adoption of the metric system in our Custom Houses. It authorizes the President of the United States to invite the several Governments of the Republics of Mexico, Central and South America, Hayti, San Domingo, and the Empire of Brazil, to join the United States in a conference to be held at Washington at such time as he may deem proper in the year 1889, to consider, among other things, the formation of an *American Customs Union*, and the adoption of a *uniform system of weights and measures*. The tendency of this may be understood from the facts that each Government is to have a single vote; that, with insignificant exceptions, if any, the nations south of the United States already use in their Custom Houses the metric system, which the United States has fully legalized; and that the United States, Venezuela, Peru, and the Argentine Republic concluded with the

European nations the metric convention of May 20, 1875, establishing the International Bureau of Weights and Measures, under the control of a General Conference for Weights and Measures, whose duty it is "to discuss and initiate measures necessary for the dissemination and improvement of the metric system." We have the testimony of engineers from the United States that the metric system is used on public works in the principal countries of Central and South America.

For the Committee,

BOSTON, May 26, 1888.

CHARLES H. SWAN, Chairman.

APPENDIX.

After the reading of the report to the Society, it was voted March 21, 1888, that the Committee be authorized to print such portions of the replies to question (F) as seem desirable. Your Committee has accordingly made the following selections:

TYPICAL EXTRACTS FROM THE REPLIES.

No. 1. I am most emphatically opposed to the whole business. * * * In my opinion it is utterly and absolutely impossible to introduce the French system of weights and measures, with all its interminable decimals, into either England or the United States. * * * I oppose the French metric system because of its intrinsic defects. The meter is not a unit of length needed in this country for any of the practical operations of business or in the arts. * * * The decimal division is very convenient for some purposes, but for others it is absolutely useless. The half, quarter, eighth, sixteenth, etc., are the natural divisions of everything. * * * The meter was founded upon a myth, and its originators made a serious mistake in getting the original distance that its value was based upon.

No. 2. (From a member in practice with a mechanical corporation). Personally, I am not opposed to the introduction of the metric system. Although now perfectly familiar with our present system of halves, quarters, and eighths, in measures of length. I have no doubt a very short time would be sufficient for me to make myself at home with the metric system; the advantages of which are less apparent, or less marked in my present business. In fact. I do not doubt that many professional men would find it much more valuable to them than our present system. But I do not know of any errors or costly mistakes or business disadvantages than can be fairly charged to the present system; and I do not feel justified in asking my present superiors (who are single examples of what must be a very large class) to subject themselves to the great annoyance, the increased liability to mistakes, and the large increase in expense, all of which would follow such a change as is proposed to be eventually made.

No. 3. * * * I am entirely in favor of a decimal system throughout. My objection to the metric system is found in the unit; and it is the outcome of my practical field experience in Mexico, where the metric system was used. * * * I prefer a shorter unit.

No. 4. * * * I am glad the question has been brought up. I should like to see published, for the benefit of the Society, the arguments for and against the metric system, provided it would be done so as to give the fullest and best arguments on both sides. * * *

No. 5. I am doubtful about the metric system. The chief advantage I see is uniformity. The theoretic beauty of the metric base disappears because it never can be strictly true. The educational saving is a disadvantage if children are to grow up ignorant of vulgar fractions.

Some other disadvantages, briefly, are: 1. The meter and yard are unhandy measures for engineer's use. The foot is a "survival of the fittest." The unit of a system should be small enough to favor whole numbers rather than fractions. 2. The great expense, mechanically, of a change. 3. The decimal system lacks the $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{16}$. Therefore, I still use inches and eighths, although the decimals of a foot are quite at my tongue's end. I should be willing to make great personal sacrifices to secure an octonal or similar system of numerals.

I do not feel the present system of measures oppressive, or chafe under it in my business, which is that of a railroad and sewerage engineer.

What I desire on this question is more evidence from unprejudiced business men of foreign countries who have *actually been through the change*.

No. 6. (From a Member in hydraulic practice with a corporation.)
* * * At this office are several members of the Society. Much of their time is given to computations and calculations which embrace decimal and common fractions and metrical measures. Habit renders the transposition from one system to the other an easy matter, and there seems to be no immediate call for the proposed change.

If the change is made, the assistants here would very quickly become familiar with the new methods, and the work would go on as now, with a probability that the labor would not be much, if any, less fatiguing than under the present system.

I am inclined to advocate moving slowly in the way of arbitrary legislation, believing that it is better to stick to the present system until a more decided demand exists in the fraternity for the proposed change.

No. 7. (From a Member connected with an educational institution.)
As to the desirability of pressing the adoption of the metric system in this country I am in doubt. In my own limited experience I have not had the advantage of such a change brought to my mind strongly enough to bring about a positive opinion in its favor; so that while I can see some probable benefits to arise from the introduction of the metric system in the United States, those advantages are with me at present theoretical only, and not yet convincing.

I am strongly of opinion that our own system of weights and measures could with advantage be simplified and a less number of units employed than now, and that any changes adopted should be in the direction of a decimal scale. I do not think the standard units employed in the metric system are so convenient in absolute size, or so well suited to the conditions of the ordinary transactions of life, as some of the units now in use among us.

I think the metric system can doubtless be employed with advantage among certain classes of scientific men, who have more direct concern with the weights and measures of other nations than do the mass of the people. But I do not as yet feel that it should be forced upon the country in any way. I rather entertain the belief that if it has such great ad-

vantages as have been claimed, it will win its own case, and will come into general use through concerted private action. When that movement shall have gone far enough, the passage of laws may be desirable to make the adoption of the system unanimous.

No. 8. My replies (affirmative) to these questions are not based upon the results of any special study, for I have made no study at all of the subject; but upon the general principle that as measurements are universal and must be exchanged and transferred from one end of the world to the other, it will be worth considerable trouble and expense to secure uniformity in methods and standards throughout the world.

No. 9. I favor the ultimate exclusive adoption of the metric system; although I do not feel disposed to grant that it is better than the foot (decimally divided of course) for the purposes of engineering and surveying. My objections to the metric system may be summed up by saying that the meter seems to my mind an exceedingly ill chosen unit in point of size. * * * Considering, however, the fact of its adoption by so many European nations and by scientific men in general, I am strongly in favor of the United States compelling by law its use after a certain date.

No. 10. I have long considered the system of weights and measures in use in this country an antiquated absurdity, and have hoped to see a simple and consistent decimal system adopted in its place. * * * The fact that the meter has become the standard of so many nations, makes the adoption of any other by the United States a half-way measure, that would leave us only half as well off as we ought to be if we propose to make any change at all. I should be glad to see the metric system, in its entirety, in general use in this country; and its adoption by the government in its several departments would prove a strong entering wedge.

No. 11. The National Electric Light Association, after a careful and exhaustive investigation of the subject of wire gauges by a very competent committee, voted to have standards of the new gauge recommended by that committee prepared and distributed; viz.: a gauge specifying the diameters of sizes in thousandths (?) of a millimeter; *i. e.*, virtually the adoption of a decimal gauge in the metric system. The Edison Electric Light Company adopted for their systems a gauge based on thousandths of an inch of diameter; but are the only ones I know of who use this exclusively.

No. 12. * * * Some idea of the magnitude of the saving effected by the adoption of the metric system may be obtained from the following considerations:

An estimate, worthy of confidence, of the saving in the teaching of arithmetic in schools was published in the Proceedings of the American Metrological Society, Vol. 2, p. 193, in these words: "A schoolmaster who has had experience both in New England and in the West, and has taught the metric system, has made a careful detailed estimate; he puts the length of the arithmetical course at 162 weeks, and thinks it could be reduced to 88 weeks by substituting the metric system for our old weights and measures. The saving of 74 weeks, or 46 per cent. of the course of study in arithmetic, pursued simultaneously with other branches, would probably amount to nearly a half-year solid of school

life." Assuming the whole length of school life even at so extravagant a figure as ten years, the saving for more useful purposes would thus be five per cent. of the child's education, which is an important item. According to the report of the United States Commissioner of Education for 1884-5, the expenditures for public schools in all the States and Territories of the Union in that year amounted to upwards of \$110,000,000, of which nearly \$66,000,000 was paid for the salaries of teachers. A saving of 5 per cent. per annum on \$110,000,000 is \$5,500,000. Capitalized even at the excessive rate of 10 per cent., this gives \$55,000,000 as the amount which it would on this basis appear that the United States could afford to pay out now, if it could by so doing get rid immediately of the perpetual annual expense hereafter of teaching ancient weights and measures in public schools. Private schools would have to be added to this to get a complete estimate even of school instruction. The number of children enrolled in the public schools was upwards of 11,000,000; hence, \$5 for each child is the rate of the above \$55,000,000 estimate; the number of "teachers and scientific persons" in the United States, according to the census of 1880, was nearly 238,000, while upwards of 17,000,000 of other persons were classed as having occupations. How much would the introduction of the metric system save these other 17,000,000 citizens? Evidently the waste of effort by the use of bad weights and measures after they were once familiar would be a less proportion than the waste of effort to learn them at first: but if, instead of 5 per cent. it were 1 per cent., or $\frac{1}{10}$ of 1 per cent., on the industry of the 17,000,000 persons having occupations in the United States, and 1 per cent., or $\frac{1}{10}$ of 1 per cent., on every citizen's income, it is a matter that we cannot afford to ignore.

That a valuable proportion of the labor that is expended upon business calculations could be saved by the substitution of the metric for the old weights and measures, cannot be doubted by any one who compares a few tables, such as have been in use for reference, with the corresponding ones appropriate to the metric system; although the contrast of calculations, if the tables were once made, and were known to be correct, and were always at hand when wanted, would obviously be less than that of the tables themselves. * * *

In science the United States as well as Great Britain has already changed to the metric system, and in business the change to the metric system is now going on; and the disproof of the allegation that it is impracticable is to be found conspicuously in such descriptions of the process as the following passages extracted from the discussion on British and metric measures which took place in the Institution of Civil Engineers, London, January, 1885 (Proceedings Inst. C. E., Vol. LXXX., Part II., reprinted in *Van Nostrand's Engineering Magazine*, September-November, 1885).

Mr. Percival Fowler said "he could speak from practical experience that in Spain, in a week, the workmen became thoroughly conversant with meters, centimeters, and millimeters, and he was certain that the difficulty of changing the English system of weights and measures to the decimal system had been greatly over-estimated."

Mr. Hamilton-Smythe said "In Austro-Hungary, for instance, the

metric system was extensively used by engineers for their own convenience for some years previous to its general introduction. It had become the interest of contractors and workmen to make themselves acquainted with the terms of measurement, in which the plans, specifications and bills of quantities supplied to them by their employers were expressed; and thus through the medium of the working class a knowledge of the system had been extensively spread through the mass of the people before the system was made legally compulsory for the purposes of general commerce."

"Mr. C. L. Hett remarked that in 1870 the Butterley Company obtained the contract for the Dordrecht Railway Bridge, and he had prepared the drawings for the steam cranes, scaffolding, etc., required in its erection. As the piling and superstructure of the staging had to be erected by a Continental contractor, the drawings were made to metric measures. Drawing scales were ordered with the most generally used English graduations on one edge, and corresponding metric divisions on the other. By the use of these scales all difficulty was overcome, and rapid progress made. The drawings of the bridge itself were prepared in Holland, under the supervision of the Dutch Government engineers, and were dimensioned in metric figures throughout. But in the works there was an outcry. The men at first said they could not, and would not work to such outlandish dimensions. The purchase of a few metric rules, however, settled the difficulty; and after a fortnight's practice one of the old hands who had been most opposed to them, admitted that the metric measures were much the easiest to use. * * * It should be mentioned that no member of the Butterley staff nor any of the workmen had had any previous experience of metric measures."

"Mr. F. Briffault pointed out two instances that had come under his notice in connection with two foreign water-works where the decimal and metric systems alone were used. The Brazilian Government had been supplied with 95,000 tons of pipes and connections from this country for the water-works of Rio de Janeiro, this quantity being divided between four manufactories. The castings were all weighed in kilograms, the weighing machines having been made expressly for the purpose. At first the men did not take kindly to the innovation; but at the end of a fortnight, after finding out the great saving of trouble thereby effected, they much preferred this system to the British. * * * In the case of the Constantinople water-works, similar satisfactory results had been obtained by the use of the decimal system; but in Turkey the advantage of it over the British system was even more marked. * * * The reduced lengths were measured in meters and centimeters, and the maximum weight allowed per lineal meter being fixed, the two had but to be multiplied together, and the result was metric tons and decimal parts of the same."

No. 13. Having had nearly a year's experience in the metric system as applied to linear distances on railroad work, I am heartily in favor of that system.

No. 14. I believe, from experience, in using other measures than those we now employ, that the adoption of the metric system would be attended with much less trouble and cost than is generally anticipated.

No. 15. (From a Member in active municipal practice.) I used the metric system of weights and measures exclusively for eight years while connected with the United States Coast Survey, and fully appreciate its advantages over the composite American system now in use. All my more important computations in my office are now made in the same system, as I think I save time in the end to reduce all my measures to meters before computing.

I believe the metric system the best for the reason that it is now, and has been for some years, the system in use by nearly all scientific writers. The meter itself must be considered an arbitrary standard. But I see no objection to that; the standard bar has been duplicated so many times it is impossible to lose it, and our old system is no better off. In practice I never felt that a long standard of 39 odd inches interfered at all with my work; and in fact for long distances it has many advantages over the short standard of 12 inches.

It seems to me that the question is one of decimal or binary divisions, and not on the value of the standard. That being the case, the decimal system now in part universally used has advantages over any new standard that can be devised. I use the old standard in my office for the sole reason that the new is not legalized, and I do not wish to make an innovation that may be changed by a new incumbent of the office. If the new system is made compulsory dating from a certain time, it will be a surprising matter how *quickly* every body will take hold of it. The trouble now in using it, lies not so much in ascertaining dimensions in meters, as in trying to express equivalents to feet and inches; or in thinking in one system and working in another. The use of the metric system, *as such*, and the handling of metric weights and measures, would quickly bring a knowledge of its value and simplicity.

I have dwelt only on the lineal measures because they apply directly to my work. I think, though, that the other measures have even better points than the lineal; mainly because every one is connected to the others in such a way as to make it possible to compare values without numerical reduction, which is impossible in our system.

PRESERVATION OF THE APRON AT THE FALLS OF ST. ANTHONY.

BY ARCHIBALD JOHNSON, MEMBER OF THE CIVIL ENGINEERS' SOCIETY
OF ST PAUL.

[Read January 9, 1888.]

Before touching on the subject of this paper it may not be out of place to give a brief description of St. Anthony Falls and of the main works constructed for their preservation.

The bed of the river at Saint Anthony Falls is a stratum of magnesian limestone, overlying a soft sand rock of an unknown depth, and which wears away rapidly under a strong current of water. This stratum of limestone only extends about 1,200 feet above the crest of the falls. A section through it in the direction of the channel of the river, is nearly

triangular in shape. At the crest of the falls it is about 16 feet thick, and at the foot of Nicollet Island, it terminates in a thin layer.

The depth of the fall varies somewhat with the stage of water in the river, but it is never far from 43 feet. How far the falls extended

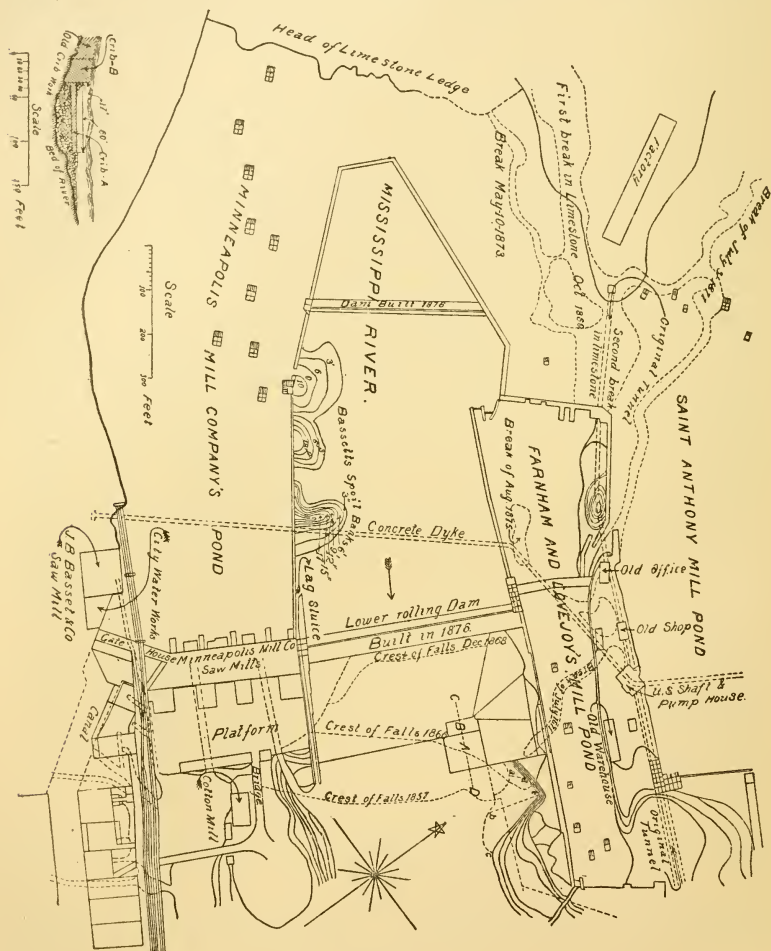


Fig. 1.

Falls of St. Anthony, Minnesota.

Scale : 1 inch = 450 feet.

NOTE.—Contours show original shape of spoil banks, as surveyed in 1882, and are referred to a stage of water 12 feet above the crest of the lower rolling dam.

a b c = Line of face of sand and lime rock in 1881.

d e c = Line of face of sand and lime rock in 1882.

down the river, I am not prepared to say. It is supposed by some that they extended as far as the confluence of the Mississippi with the Minnesota River, but there are unmistakable evidences that they

extended as far at least as the head of Meeker's Island. These evidences are the visible masses of limestone in the bed of the river which fell from the ledge.

The recession of the falls was caused by the sand rock wearing away, and thus undermining the limestone ledge and allowing it to break and fall in large masses until the destruction was arrested by improvements. In 1857 the Territorial Government of Minnesota granted a charter to two water power companies at Minneapolis, allowing them to construct dams and other improvements in the bed of the river. The result was that the river at the crest of the falls was contracted from a width of 1,250 feet to about 445 feet. After this was done the recession of the falls was very rapid, for from 1857 to 1868 they had receded in the narrow space not closed a distance of 300 feet. In addition to narrowing up the channel, a tunnel, known as the Eastman Tunnel, was excavated under the limestone ledge, commencing a short distance below the end of the ledge at the east channel and terminating near the foot of Nicollet Island. It was 6 feet square, and the roof was 6 feet below the limestone ledge. It was without lining of any kind. It was commenced in September, 1868, and completed in the fall of 1869, and was intended for a tail race from mills which were to be located on Nicollet Island. When the tunnel was completed, the water broke into it under the head of the limestone ledge, and it was not long before the water rushed through it in torrents. As the sand rock was soft it wore away rapidly, and the ledge was therefore left unsupported. Several breaks occurred in the ledge in the vicinity of the tunnel from 1869 to 1871, and various expedients were resorted to in checking the flow of water through it, but at first all attempts were failures. The recession of the falls was another source of anxiety, and in 1866 the water-power companies made an attempt to protect the falls by a timber apron, but the first high water destroyed it. A second attempt was made in 1869. In 1870 the citizens of Minneapolis, realizing that there was danger of the falls going out, invited J. B. Francis, the eminent hydraulic engineer, to examine the falls. He recommended a substantial apron of timber on the slope of the falls, with heavy cribwork at the bottom. He advised the uncovering of the tunnel for a distance of about 400 feet from the second break in the limestone ledge, and filling it with a puddle of clay and gravel. He also recommended the construction of low dams to keep the ledge constantly covered with water. Franklin Cook, a civil engineer of Minneapolis, had previously made this recommendation, and the object was to prevent the disintegration of the ledge by the action of the frost. In 1870 the aid of the general government was invoked to save the falls. Accordingly on July 11, 1870, Congress appropriated \$50,000 for improving St. Anthony Falls. This was the first appropriation made by Congress. The plan adopted by the U. S. army engineers was essentially the same as recommended by Mr. J. B. Francis, but with the addition of a concrete dike under the ledge, extending from shore to shore. It is from 4 to 6 feet thick, and extends into the sand rock about 40 feet below the ledge. The object of it was to cut off all running water under the ledge, and the plan was successful. It was completed in 1876. The tunnel

above the dike was filled; the apron built by the citizens of Minneapolis on the slope of the falls, was extended and remodeled, and two rolling dams, each about 5 feet high, one at the crest of the falls and the other some distance above, were built to keep the ledge at all times flooded. The length of the lower rolling dam is about 445 feet, and it is over this space that all the water of the Mississippi passes, with the exception of what is used by the mills. The width at the toe of the apron, however, is only 355 feet. The apron consists of two planes, the principal one passing through the crest of the lower rolling dam, and is about 243 feet long with a slope of 5 horizontal to 1 vertical, and the other passing through the crest of the ledge along Farnham and Lovejoy's dam, and having a slope of about $2\frac{1}{2}$ horizontal to 1 vertical. The portion of the apron forming this latter slope is termed the east wing, and it extends down about 100 feet below the toe of the main apron, and the line of its toe is nearly at right angles to that of the other. The apron is built of cribwork filled with stone, and is covered first with a course of 8-inch timber, and that with a course of 4-inch plank. The intersection of the two planes is termed the angle of the apron, and a space about 100 feet square between the east wing and main apron is also termed the angle.

After the main apron was completed in 1878, it was evident that the toe should in some way be protected from the scouring action of the water, and riprapping was naturally resorted to. In remodeling the apron on the westside, 5,700 cubic yards of limestone were excavated and used in protecting the toe of the apron. In addition to this, 2,300 cubic yards of granite boulders were dumped in at the east end of the apron to fill up a large hole there, and to riprap the crib-work at the toe. When this riprapping was completed it was believed that the apron was secure, the riprapping then reaching nearly to the surface of the water. Before this riprapping was done, there was a depth of 62 feet near the toe of the apron in the angle. In September, 1879, an examination was made at the toe of the apron in the angle, and it was found that there was a depth of 17 feet at the toe, and a depth of 30 feet a short distance out from the angle of the two planes of the apron. Shortly after this 250 cubic yards of limestone blocks weighing from 1,000 to 2,000 pounds were thrown in the angle. Another examination was made in September, 1880, when a depth of 29 feet was found at the toe of the apron in the angle, where in 1879 the depth, when first examined, was but 17 feet. About 60 feet from the angle of the apron and in the direction of the current a depth of 33 feet was found, where in 1879 the depth was 30 feet. In September, 1882, a depth of 34 feet was found at the toe of the apron in the angle, and 41.5 feet at a distance of about 40 feet from the toe of the main apron and that of the east wing. The corresponding depths in 1879 were respectively 17 and 30 feet. This gradual deepening shows that riprapping was a failure. All the riprapping along the toe of the apron had disappeared after the first floods. This is owing to the high velocity at flood stages, being not less than 50 feet per second, and aggravated at the angle by a powerful eddy that forms about 200 feet below the foot of the apron, and sweeps back along the east wing.

In September, 1882, flush boards were put on the crest of the lower roll-

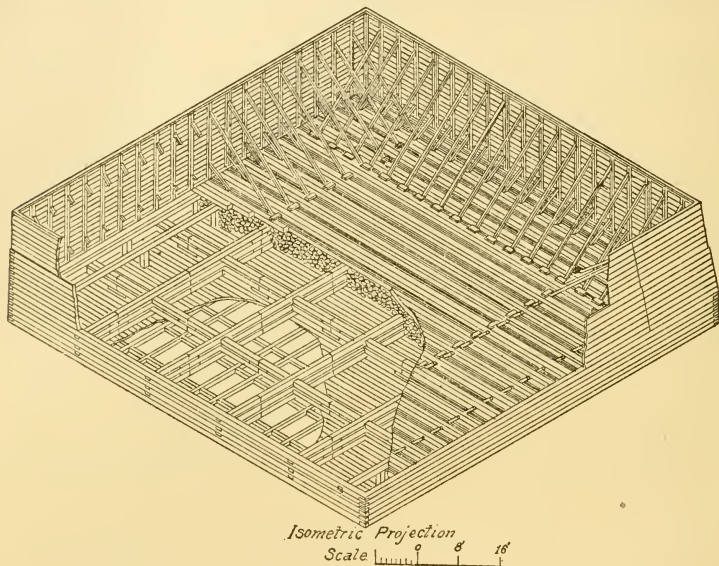
ing dam for about two-thirds of its length from the east end, thus exposing about one-half of the apron. Soundings were taken along the main apron for a distance of 100 feet west from the east wing, and down stream about 180 feet. The cribwork of the toe of the main apron for a distance of 75 feet west from the angle and back for a width of 26 feet was entirely destroyed. As far west from this as the toe of the main apron could be examined the cribwork was without rock, and was afloat. The lower corner of the east wing had settled 13 feet from the undermining action of the eddy. The situation was certainly alarming, and the problem was what to substitute for riprapping to prevent the cribwork at the toe of the apron from being destroyed by the scouring and undermining action of the falls. Riprapping of boulders of such sizes as could be conveniently handled proved a failure, and there was no known precedent in engineering construction to answer the case. The idea was conceived to sink a covered crib of such dimensions and specific gravity as would not be disturbed by the action of floods. In the fall of 1882, a design of such a crib was accordingly made. The first work to be done, however, was to repair the space of 26 feet by 75 feet at the toe of the main apron in the angle, and afterward to level up a space in the angle to receive the covered crib. The apron was renewed in this space by sinking two cribs. The first was 26 feet wide, 67 feet long and from 28 to 32 feet deep in front, and 8 or 10 feet less depth in the rear. The other was 8 feet long in front, 20 feet wide and 26 feet deep. For a distance of two-thirds from the front of the cribs there was a flooring, so as to enable us to sink them, as they were built by loading them with rock. After they were sunk they were filled with rock and covered with 8 and 4 inch plank.

The framing of the crib to be sunk in the angle was commenced by a small crew about the 11th of December, 1882, but no material was put in place before the 1st of January. The construction of the crib was commenced on the ice in the recess or enlargement, and about ninety feet below where it was to be sunk. This was done so that the work of leveling the bed of the river in the angle could be carried on while the crib was being built. The bottom of the river was leveled by throwing rock at random in the deepest places, until the depth was reduced to 26 or 28 feet. After that the rock was lowered by means of grappling irons until the depth was reduced to 24 feet. A space 90 by 90 feet in the angle was leveled in this way. Before lowering rock with the grappling iron, a rope was stretched along the outer side of the area to be leveled and a sounding made at the end of the line. Whenever the sounding was $24\frac{1}{2}$ feet or over, rock of suitable size was lowered to the foot of the sounding rod by means of a rope. The sounding rod, which was made of gas pipe, was passed through a ring on the grappling iron to guide it to the foot of the rod. When a distance of 90 feet had been gone over in this way, the rope was moved one foot parallel to its first position. Soundings were taken and rock lowered as before. The same process was repeated until the entire space was gone over. Soundings were then made over the entire area of 90 by 90 feet, and the depth in no place varied six inches from 24 feet.

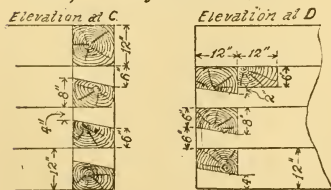
The crib for the angle was built 80 feet square, with walls 6 feet

high. The depth of filling was 4 feet ; and it was filled with rock and grouted with sand and hydraulic cement. It was constructed as follows :

The floor beams were constructed of 9 inch by 9 inch timbers, spliced together with a ship lap 2 feet long, and fastened by two $\frac{3}{4}$ inch screw bolts. Their ends are fastened to the lower timbers of the walls of the crib by 3 inch by 5 inch tenons. They are 4 feet apart, and every 8 feet



Plan of Framing at corner of Crib.



Section through floor



Fig. 2.

Crib Sunk March 6, 1883; in Angle at Foot of Apron.

MAJ. C. J. ALLEN, U. S. A., *Chief Engineer.* ARCHIBALD JOHNSON,
Assistant Engineer.

are struts of 9 inch by 9 inch timbers to stiffen them laterally, and are secured to the floor beams by 2 inch by $4\frac{1}{2}$ inch tenons. Between the walls and first floor beams there are also struts. All tenons are pinned by oak tree-nails 1 inch in diameter. The flooring was sized down to 4 inches by 12 inches in a planer, and each side of the plank had a $\frac{3}{4}$ inch by $\frac{3}{4}$ inch groove in it. The top of the groove was 2 inches from the

top of the plank. As the planks were laid these grooves were coated with white lead, and a tongue of seasoned pine, $\frac{3}{4}$ inch by $1\frac{1}{2}$ inches, inserted into it. The planks were then spiked to the floor beams with two $\frac{3}{4}$ inch by 8 inch boat spikes at each intersection, and two at the ends. Screw-bolts, $1\frac{1}{2}$ inches by 6 feet $3\frac{1}{2}$ inches, with a collar 16 inches from the lower end, to connect the covering with the floor beams, were put in 4 feet apart as the flooring was laid, with a rubber packing under the collar. The collar was hexagonal, so as to hold the rod from turning while the nut was being tightened under the floor beam. The rubber packing was to prevent water from coming up along the rod. All the joints of the floor were calked and pitched as fast as it was laid.

The outer walls were built of 12 inch by 12 inch square timber, and sized on two sides to an exact thickness of 12 inches. This sizing was done to insure close joints for calking. When wall timbers are adzed the workmen are apt to hollow out the timbers, and it is difficult to calk the joints. As the outer walls were being built the space inside was divided into squares of about 16 feet by cross walls of 12 inch by 12 inch timber resting on the flooring. The ends of these timbers forming these cross walls were dovetailed into the outer walls, and where they crossed one another each one was gained $1\frac{1}{2}$ inches. The first two courses in the outer wall were fastened together by 1 inch screw bolts, 4 feet apart. The next four courses were fastened together by oak tree-nails 2 inches in diameter and 2 feet long, and 1 inch by 30 inch drift bolts of round iron. The joints in the walls were then calked and pitched. The crib was now towed to its position in the angle, and a curbing 16 feet high constructed on the outer walls to keep it afloat while it was being filled and covered, and to lower it gradually to the bottom after it was completed. The curbing was constructed by setting 6 inch by 6 inch by $16\frac{1}{2}$ feet posts with 4 inch round tenons in the outer walls and tenoned into a 4 inch by 6 inch piece at the top. These posts were planked with 4 inch plank about half-way up, and the remaining distance with 2 inch plank. The first five courses of the 4 inch plank was then calked. The curbing was held in position by 1 inch rods passing through the 4 inch by 6 inch pieces at the top, with hooks at their lower ends hooking into eyebolts in the walls. The posts were braced with two sets of braces. The crib was then filled with rubble rock and grouted as previously stated. After it was filled it was covered with 12 inch by 12 inch timbers, every fourth one being screw-bolted to the floor beams by $1\frac{1}{2}$ inch screw bolts 4 feet apart. The covering timbers were drift-bolted together laterally with 1 inch by 20 inch drift bolts 4 feet apart, and besides fastened to the cross walls by oak tree-nails 2 inches by 20 inches, so that when the covering was completed it formed one sheet connected with the bottom by these numerous screw-bolts. On the timbers through which the screw-bolts passed straps of iron $\frac{1}{2}$ inch by 4 inches were placed to save the bolt heads from being injured by logs striking them. When the crib was completed it was lowered gradually by letting the water in through gates at the corners. It was sunk on the 6th of March, 1883. When it settled on the bottom no part of it varied more than six inches from a level, and the depth of water over it was 18 feet. After it was sunk the curbing was detached. After sinking it, 1,042 cubic

yards of limestone blocks, each measuring from 10 to 40 cubic feet, were placed around it to prevent its being undermined. From observations made at the time of sinking the crib, its specific gravity was 1.5, and its estimated weight was 1,674 tons. The riprapping around the crib may be removed by a strong current, but it is believed to be sufficiently strong and flexible to stand considerable undermining without being broken and destroyed. In the winter of 1885 and 1886 an examination was made to see if any changes had taken place since the crib was sunk, but it was found to be still level, with no disturbance of the rip-rapping around it. Up to this time, however, there had not been any floods in the Mississippi, and no material change could have been expected. The bottom has now scoured to such a depth at the foot of the apron that it is only heavy floods that cause much damage. About one-third of the water passing over the falls is concentrated in the angle, owing to the peculiar construction of the apron, and that which is subject to greatest scour is now protected; but until the damaged portion of the apron is repaired, and the space all along the foot of the main apron is protected by submerged cribs, similar to the one just described, the apron upon which the safety of the Falls of Saint Anthony now depends will be in constant danger during flood stages. Fig. 1 shows the apron at Saint Anthony Falls as now constructed. Fig. 2 shows a plan of the crib submerged in 1883.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 20, 1888 :— A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, at 7:30 P. M., President FitzGerald in the chair, fifty-four Members and twelve visitors present.

The record of last meeting was read and approved.

Messrs. Robert Forbes, Charles E. Houghton, Robert H. Richards and Henry B. Wood were elected Members of the Society.

The following were proposed for membership :

Mr. Louville Curtis, of Tyngsboro, Mass., recommended by H. C. Keith and C. W. Drake, and Mr. William M. Scanlan, of Boston, recommended by Edward Sawyer and D. W. Pratt.

The Secretary read a communication from the Engineers' Club of Kansas City, soliciting the co-operation of this Society in a movement to secure a proper inspection of bridges; also a communication from a Committee of the Western Society of Engineers upon the same subject. On motion of Mr. Stearns, both communications were referred to a special committee of three, to report at the September meeting. The chair appointed as that committee, Messrs. John E. Cheney, David H. Andrews, and Edward S. Shaw.

On motion of Mr. Keith, it was voted to omit the regular meetings of July and August.

Mr. Lucian A. Taylor read a paper entitled " A Brief Description of the Quincy Dam."

Mr. William S. Barbour, then read a description of the dam of the Cambridge Water-Works on Stony Brook, which was illustrated by about forty stereopticon views showing the work in its several stages.

Mr. John R. Freeman described a washout which occurred on the Canal at Nashua, N. H., and read a communication from Mr. Edwin F. Smith, Engineer of Canals, Schuylkill & Susquehanna Navigation Company, giving his experience in the construction of wooden dams.

Mr. Wilbur F. Learned gave an account of some of the difficulties encountered in the construction of the Chestnut Hill and the Parker Hill reservoir, and Mr. R. A. Hale described the Essex Company's dam at Lawrence, Mass.

A general discussion followed the reading of the several papers.

On motion of Mr. Stearns, the thanks of the Society were extended to Mr. E. F. Smith for his interesting communication.

[*Adjourned.*]

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 30, 1888 :—294th Meeting.—The Club met at Washington University at 8:15 P. M. President Holman in the chair; twenty-eight Members and three visitors present. The minutes of the 293d meeting were read and approved. The Secretary read the following:

"The Committee appointed by the President to consider the advisability of this Club co-operating with the Kansas City and other engineering clubs in reference

to proposed State legislation for the safety of public bridges, as indicated in the herewith accompanying report of the Kansas City Club, do unanimously agree that we regard it desirable for our Club to co-operate with them for the object specified. We deem it the duty of the Club to aid such action from both a public and professional standpoint, and think that persistent effort will succeed in finally obtaining such legislative action on this important matter, in which the engineering clubs should take the initiative.

(Signed) " H. A. WHEELER, }
 " C. H. SHARMAN, } Committee."
 " MAX G. SCHINKE, }

On motion the report was received and the Committee discharged. Moved and seconded that the chair appoint a Committee of three to co-operate with Kansas City and other engineering clubs in furthering legislation on the subject of improvements in highway bridges; carried. The Chair appointed as such committee Messrs. Robert Moore, C. H. Sharman and A. W. Hubbard. The Librarian notified the Club that Mr. Charles E. Jones had presented the library with eight bound volumes of the *Railroad Gazette*, from 1872 to 1879, formerly the property of the late Prof. C. A. Smith. On motion a vote of thanks was tendered Mr. Jones. Mr. R. E. McMath then read a paper on "The Water-Way between Lake Michigan and the Mississippi River, by way of the Illinois River." The author having been in charge of the government work on the Illinois River for some years, was able to treat the question in the light of experience. He referred to canals in general and gave special attention to the various schemes connected with the Illinois River, as well as the Hennepin Canal and the complications due to the Chicago drainage. He considered his subject under the following heads: Physical, Sanitary, Economical and Political. The author thought the scheme was of great importance and promised decided benefits. The paper was discussed by Messrs. Seddon, Professor Johnson, Wheeler, Bouton and Holman. On motion it was ordered that 1,000 copies of this paper be printed for circulation. The special order of the day was then taken up, being action on the recommendations contained in the report adopted at the last meeting, on the subject of National Public Works. The report provided for a committee on finance and one on correspondence. On balloting, the following committees were chosen: Finance, J. B. Johnson, R. E. McMath, Robt. Moore, W. B. Potter and E. D. Meier. Correspondence, J. B. Johnson, R. E. McMath, E. D. Meier, F. E. Nipher and C. M. Woodward. The meeting then adjourned.

W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JUNE 6, 1888:—The 248th meeting was held, the President in the chair.

The minutes of the last meeting were read and approved.

Mr. Lewis B. Jackson, Chicago, Ill., was elected a Member.

Applications were filed from Robt. George Turknnett, C. & N. W. Ry., Chicago, Ill., and George Eric Spaak, Wright Const. Co., Chicago, Ill.

The Secretary reported receipts since last meeting, \$61.50; cash in hands of treasurer, \$101.62; bills unpaid, \$244.75. Bills for \$51 were ordered paid.

The Secretary reported that after all dues were collected there would be a considerable deficiency at the end of the year. The Secretary was instructed to collect the additional dues of \$2.50 per Member for the year 1888, or the full annual dues as established by the By-Laws as amended by vote canvassed March 6, 1888.

The President reported that the Trustees had not yet matured any recommendations as to the future policy of the Society, but that he expected to report upon

the matter at the next meeting. He also stated that the Committee on Highway Bridges had taken action in carrying out the instructions of the last meeting. Considerable discussion occurred in regard to the functions of State Engineers in the several States and upon the general question delegated to the Committee.

Upon motion of Mr. Liljencrantz, a Committee upon Employment was ordered to consider and report at the next meeting some plan and the necessary rules for carrying it into effect, for receiving and taking action upon applications for positions or for professional assistance from Members of the Society. After some discussion, Messrs. Liljencrantz and Parkhurst were appointed as a committee.

The Secretary read a letter from Mr. W. S. Pope, announcing the death of William L. Baker, of the Detroit Bridge and Iron Works, at his home in Detroit, on May 28. After remarks in regard to Mr. Baker, and also in regard to Charles Latimer, Messrs. Weston and Liljencrantz were appointed a committee to report suitable resolutions upon the lives of Mr. Latimer and Mr. Baker.

The Secretary read a paper by Alva M. Van Auken upon "Classification of Material in Railroad Construction," and a supplementary paper upon the "Commissary in Railway Field Parties." The paper was discussed at length by Messrs. Weston, Gottlieb, Parkhurst, Liljencrantz and others. It was ordered that the paper be held until next meeting for further discussion, and that the remarks be put in writing for publication.

Upon motion the Treasurer was ordered to insure the library and property of the Society for \$2,000 to January 1, 1890.

The next meeting was fixed for July 11.

[Adjourned.]

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JUNE 12, 1888 :—The Club was called to order by President Whitelaw at 8:45 P. M. Eleven members present.

Upon motion the reading of the minutes of the last meeting was dispensed with and the minutes as recorded by the secretary were approved.

The report of the Committee on Programme was read by Mr. H. C. Thompson, chairman.

After discussion of the work of the several committees for the year, it was decided that the semi-monthly meetings should be dispensed with, but that adjourned or special meetings could be held whenever necessary.

Mr. W. H. Searles exhibited some specimens of electric welding by the Thompson process, and gave a brief explanation of the process.

Mr. Whitelaw, in the name of Mrs. Simeon Sheldon, presented the Club with three works on engineering.

Upon motion of Mr. N. B. Wood, the thanks of the Club were tendered to Mrs. Sheldon.

The meeting was then adjourned till the second Tuesday in July.

JAMES RITCHIE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

JUNE 4, 1888 :—A regular meeting was held in the Club-room at 7:45, Mr. T. F. Wynne in the chair. Those present were: Messrs. Jenkins, Stern, G. W. Pearsons, Waddell, Marsteller, Swain, Wynne, Breithaupt, F. L. Miller, Duncan, Potter, Kerr, Elmore, Allen, and nine visitors.

The minutes of the preceding regular meeting and the meeting of the Executive Committee were read and approved.

On canvass of ballots, the following were declared elected : As Members, Albert N. Connett, Bolton W. De Courcy : as Associate Member, Victor M. Witmer.

The Secretary reported the following contributions to the library received during the past month: "Some Applications of Graphical Statics", Chicago Chapter American Institute of Architects, Jas. R. Willett; Official Railway List, 1888, Railway Purchasing Agent Company, Chicago; Transactions Engineers' Club of Philadelphia, December, 1887; Journal New England Water-Works Association, March, 1888; Report Illinois Society Engineers and Surveyors, January, 1888.

With reference to bridge reform, the Secretary presented, by title, letters from the American Society of Civil Engineers, Engineers' Club of St. Louis, Western Society of Engineers, Civil Engineers' Association of Kansas, Cincinnati Society of Engineers, Cleveland Engineers' Society, most of them expressing a desire to co-operate.

On motion of Mr. Waddell it was voted that a committee be appointed to arrange for an excursion of the Club sometime during the summer. The chair appointed Messrs. Breithaupt, Marsteller and Stern to act as such committee.

The Secretary read a letter of regret from Mr. Donnelly at being unable to read his paper that evening, but promised it at an adjourned meeting which it was decided to hold June 18th; also a letter from Prof. Fulton, saying that he should give up his rooms in the Deardorff Building July 1st, and asking the Club to meet in his new rooms in the Y. M. C. A. Building, if they desired. The matter was referred to the Executive Committee.

The paper of the evening, entitled "Crossing of the Chicago, Sante Fe & California Railway over the Missouri Pacific and Chicago & Alton tracks near Rock Creek Station," was then read by Mr. Breithaupt, and discussed by Messrs. Waddell, Pearsons, Goldmark, Wynne, Hoover and Stern. The bridge is a riveted pony truss, and was interesting on account of the necessity of keeping clear the several tracks over which it crossed on a skew. The discussion was chiefly with reference to the number and spacing of stringers for economy, and the effect of extreme rigidity in bridge superstructures.

Mr. Pearsons read a letter from Mr. John C. Trautwine, Jr., soliciting subscriptions in aid of the family of the late W. R. Kutter, of Berne. On motion of Mr. Waddell, Mr. Pearsons was chosen to collect such subscription and forward through Mr. Trautwine to Berne.

[Adjourned.]

KENNETH ALLEN, Secretary.

JUNE 18, 1888:—An adjourned meeting was held in the Club-room. Those present were Messrs. Knight, Donnelly, Wynne, Waddell, Kerr, F. Allen, Breithaupt, G. W. Pearsons, Witmer, Farnsworth, Potter, Marsteller, F. L. Miller, Mason, K. Allen and two visitors.

Minutes of the last regular meeting and of that of the Executive Committee were read and approved.

On motion of Mr. Wynne, it was voted that, if desired by the Club, the Members attending the Milwaukee Convention make known to the American Society of Civil Engineers its desire to have the next annual convention held in Kansas City.

Amendments by Mr. G. W. Pearsons were carried to the effect that the sense of our Club and of the business and railroad men of Kansas City be obtained by letter ballots and circulars, respectively.

A letter from Mr. C. L. Strobel, of the Western Society of Engineers, with reference to "Bridge Reform," was read asking the following questions :

1. Do you favor the appointment of a State Engineer ?

Do you consider it desirable for bridge engineers to adopt a scale of minimum rates for preparing working plans and specifications for bridges ?

3. Are you willing to co-operate with this Society by the appointment of a committee to consider and report on the subject of a scale of minimum rates?

On motion of Mr. Pearsons, it was voted to get answers to these questions from the Club by letter ballot, and on motion of Mr. Wynne, it was decided to express a willingness to co-operate in general in the matter, but that definite answers could not be given until reports from our Bridge Reform and Executive Committees were received.

The Secretary presented for Mr. Breithaupt a framed photograph of the bridge described in the paper read June 4. Also, the following were received for the library: Journal New England Water-Works Association, Proceedings Engineers' Society of Western Pennsylvania, Proceedings American Society of Mechanical Engineers for 1888, Proceedings Engineers' Club of Philadelphia, List of Members Boston Society of Civil Engineers, List of Members Kansas City Club.

The Secretary reported the following subscriptions to the Kutter fund:

Geo. H. Nettleton, \$10; R. P. I., '79, \$5; Matt Hoffett, E. A. Harper, B. R. Whitney, H. Carter, A. N. Stalnaker, E. Saxton, Captain Bourke, B. W. De Courcey, M. N. Wells, Kenneth Allen, J. F. Wallace, F. L. Miller, Wm. B. Knight, J. A. L. Waddell, J. H. Lasley, Alex. Potter, B. R. Whitney, Jr., B. L. Marsteller, John Donnelly, G. W. Pearsons, R. C. Pearsons, W. H. Breithaupt, \$1 each—\$22; total, \$37.

Mr. John Donnelly read a paper on "Street Pavements of Kansas City," which was discussed by Messrs. Mason, Knight, Pearsons, Wynne, Farnsworth and others.

The following were proposed as Members: Edmund Saxton, by Wm. B. Knight and K. Allen; Walton Clark, by H. A. Keefer and K. Allen.

[Adjourned.]

KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

Address. *President's, Illinois Society of Engineers and Surveyors.* By I. O. Baker. Points out desirable changes in engineering practice of building roads, bridges, etc. *Rep. Ill. Soc. Engrs. and Surveyors*, 1888, pp. 14-27.

Boilers, *Deterioration of.* By J. M. Allen. A Sibley College lecture, treating of errors in boiler construction, and of the natural cause of their deterioration. Illustrated. *Sci. Am. Supple.*, June 9, 1888.

—, *Strains in Locomotive Boilers.* A paper read at the Nashville meeting of the American Society of Mechanical Engineers. By L. S. Randolph, Mt. Savage, Md. Showing that the failure of locomotive boilers is generally due to unequal expansion and contraction of the fire-box sheets. *American Engineer*, May 16, 1888.

—, See Oil Burners for.

Bridge, *Ben Rhydding, Eng.* Gives brief description, with two-page plate of detailed drawings, of two lattice arches, with suspended roadway, over the River Wharfe, near Ben Rhydding, Yorkshire. *Engineer*, May 25, 1888.

—, *Cairo.* By S. F. Balcom. Gives brief description of the Cairo Bridge, and describes some of the details of construction and progress of the work. *Rept. Ill. Soc. Engrs. & Surveyors*, 1888, p. 75-84; and *Railroad Gazette*, June 1, 1888.

—, *Fort Madison.* By W. W. Curtis. Gives a good description of location and construction of Chicago, Sante Fe & California railroad bridge across the Mississippi River at Fort Madison, Ia., with cuts showing details of caisson and piers. *Engin. News*, June 2 and 9, 1888.

—, *Poughkeepsie.* By Thomas C. Clark. The second Sibley College lecture describing the erection of bridge over the Hudson at Poughkeepsie. *Sci. Am. Suppl.*, May 19, 1888.

—, *Red River Concrete Piers.* By C. D. Purdon. Gives details of the construction of concrete piers for the St. Louis & San Francisco R. R. bridge over Red River, Texas. *Engr. News*, June 2, 1888.

Bridges, *Highway.* By J. O. Wright. Discusses the present practice of building highway bridges and gives hints for improvements. *Rpt. Ill. Soc. Engrs. & Surveyors*, 1888, pp. 60-65.

—, *Improved Highway.* By J. H. Burnham. Discusses the improvements made in highway bridges. The discussion on the paper relates mostly to the use of brick in place of stone. *Rpt. Ill. Soc. Engrs. & Surveyors*, 1888, pp. 47-54.

—, *Selection and Maintenance of.* By D. W. Mead. Gives hints relating to the selection and maintenance of bridges for cities. *Rep. Ill. Soc. Engrs. and Surveyors*, 1888, pp. 65-68.

—, *Specifications for Iron.* By I. O. Baker. Gives specifications relating to ultimate strength, elongation and fractured area. *Rpt. Ill. Soc. Engrs. and Surv.*, 1888, pp. 55-57.

—, *Test of Full-size Floor Beam.* By A. P. Boller. A paper before the American Society of Civil Engineers, giving details of the testing of a full-size wrought-iron double track floor beam. Abstracted *Sci. Am. Supple.*, June 2, 1888.

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BOOKS.

BAKER, B. Long and Short Span Railway Bridges. Illus. \$2.00.

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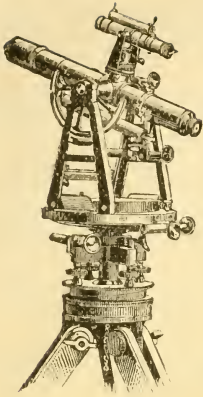
- Cables, Chain.** A full discussion of the determination of the character of iron best adapted for chain cables, the best form and proportions of links, with details of the testing of a large number of specimens. *Report U. S. Board on Testing*, Vol. I., 1881, pp. 1-238.
- Canal, Panama, Actual Status of the.** Gives a carefully prepared article, with official profile and cuts from photographs, showing the actual condition of the work. *Engr. News*, June 2 et seq, 1888.
- Car, Coal, 60,000 lbs. Capacity.** Gives drawings of a 60,000 lbs. capacity coal car for the Georgia Pacific Railroad. *Nat. Car and Loco. Builder*, June, 1888.
- , *Standard 50,000-lb. Freight.* Gives brief description with drawings and bill of material of the standard 50,000-lb. freight car of the Lehigh Valley Railroad. *R. R. Gazette*, June 8, 1888.
- Car Heating, Steam, Notes on.** By W. F. Baldwin. A paper before the American Society of Mechanical Engineers. Gives experience gained while making experiments on the Long Island Railroad. *Engin. and Build. Rec.*, May 12, 1888.
- Cements, How to Test the Strength of.** By J. Sondericker. Gives a description of an apparatus for testing cements, and presents some of the results obtained. *Jour. Assoc. Engin. Soc.*, June, 1888, Vol. VII., pp. 207-222.
- , *Lime and Hydraulic.* By F. W. Gibbs. Treats of the sources, composition and properties of limes and cements. *Trans. Arkansas Soc. C. E., Arch. and Surveyors*, Nov, 1887, pp. 38-46.
- Culvert, Railroad.** By E. A. Hill. Gives details of the building of a culvert for the drainage of about 1,600 acres of land; shows plans, cost, etc. *Rept. Ill. Soc. Engrs. and Surveyors*, 1888, pp. 28-42. *R. R. Gazette*, May 25, 1888.
- Electrical Resistance, Compensated Standards of.** Paper read before the American Institute of Electrical Engineers, May 16, 1888. By Edward L. Nichols. Describes a method of making a standard of resistance unaffected by temperature, by combining copper and carbon. *Electrical Engineer*, June, 1888. *Electrical World*, June 9, 1888.
- Electrical Stresses.** By A. W. Rucker and C. V. Bays, before the Society of Telegraph Engineers and Electricians. An interesting paper on some phases of static, electricity. Illustrated. *Sci. Am. Supple.*, May 19.
- Electricity. Construction of Plant.** By Elihu Thomson, before the American National Electric Light Association. Discusses the insulation and installation of wires and the construction of plants. *Tel. Jour. & Elec. Rev.*, March 23, 1888.
- , *Projection of Lines of Force.* By J. W. Moore. Gives an illustrated description of the use of the lantern in obtaining direct optical projections of electro dynamic lines of force and other phenomena. *Sci. Am. Supple.*, April 21 and 28, 1888.
- , *Standardizing Electrical Instruments.* By A. W. Meikle, before the Physical Society of Glasgow University. Gives a description of an application of the electrolysis of copper sulphates which has been employed for standardizing purposes in the Physical Laboratory of Glasgow University for the last two years. *Tel. Jour. and Elec. Rev.*, March 23 et seq, 1888.
- , *Transformers vs. Accumulators.* By R. E. Crompton, before the Society of Telegraph Engineers and Electricians. A valuable paper, presenting facts and figures relating to the distribution of electricity by accumulators as transformer vs. transformers. Discussion. *Tel. Rev. and Elec. Rev.*, April 20 et seq.
- Electric Batteries. The Possibilities and Limitations of Chemical Generators of Electricity.** A paper read before the Am. Inst. of Electrical Engineers, May 16, 1888, by Francis B. Crocker. Shows what can be expected of any given combination of materials, and gives table of the cost per horse-power per hour of voltaic battery energy, with different materials. *Electrical World*, May 26, 1888; *Electrical Engineer*, June, 1888.
- Electric Furnaces.** By E. J. Houston. Describes some of the early electric furnaces. *Tel. Jour. and Elec. Rev.*, April 6, 1888.
- Electric Motors, for Alternating Currents.** Paper read before the American Institute of Electrical Engineers May 16, 1888. By Nikola Tesla. A new principle in electric

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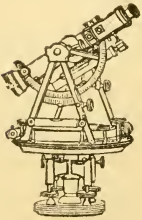
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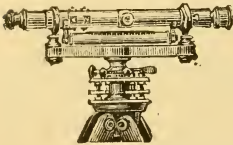


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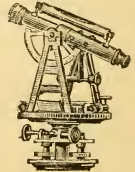


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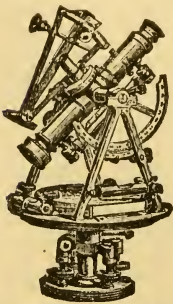
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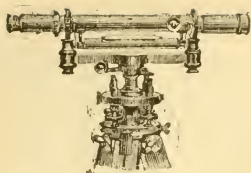
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- motors, apparently the most practical scheme yet proposed for alternating current work; also some remarks on transformers. *Electrical World*, June 2, 1888; *Electrical Engineer*, June, 1888.
- Electric Light, Cost of Arc Lighting.** A paper read by C. M. Keller before the Western Gas Association. Giving the running expenses for a number of cases for Thomson-Houston and American Arc Lights. *Progressive Age*, June, 1888.
- . *Independent Engines.* A paper before the American National Electric Light Association, by William L. Church, discussing the advantages of independent engines, over the system of concentrated power, for incandescent lighting. *Tel. Jour. and Elec. Rev.*, April 13, 1888.
- . *Underground Wires of.* By W. W. Leggett, before the National Electric Light Association. Discusses the difficulties of putting the arc light wires underground. *Tel. Jour. and Elec. Rev.*, April 6, 1888.
- Engineering, Agricultural, in India.** A series of, articles on irrigation, with the side issues, geological, social and financial, which must be considered in an extensive scheme. *Engineering*, April 6 *et seq.*, 1888.
- Engines, Volatile Vapor.** By A. F. Yarrow before the Institution of Naval Architects. Discusses the possible advantage of using highly volatile liquids in lieu of water for the purposes of propulsion. Describes a launch propelled by a volatile hydrocarbon. *Engineering*, April 9, 1888.
- Excavators, Steam.** By W. L. Clements before the American Society of Mechanical Engineers. Describes the general construction of steam excavators, and then gives detail of a special machine. Abstracted, *R. R. Gazette*, May 11, 1888; also *Eng. News*, May 26 *et seq.*, 1888, and supplemented by information from other sources.
- Foundations, Supporting Power of Soils.** By Randall Hunt. Treats of the supporting power of soils as deduced from personal observation and the recorded examples. *Jour. Assoc. Eng. Soc.*, June, 1888, Vol. VII., pp. 189-196; *Eng. News*, June 16, 1888.
- Fuel, Liquid.** See Oil Burners.
- . *Petroleum Oil vs. Coal.* By C. E. Ashcroft. Considers theoretically and practically the use of petroleum oil as fuel in place of coal. Gives valuable comparisons of test trips on the Russian railroads. *Am. Manuf.*, May 25, 1888.
- Gas, Compressed Oil Gas and its Applications.** By Arthur Ayres before the Institute of Civil Engineers. Discusses the application of compressed oil gas to light-houses, railroad cars etc. Describes the Pintsch works at South Foreland. *Engineering*, April 13, 1888. Abstracted. *Sci. Am. Supple.*, May 19, 1888.
- Gramophone, Etching the Human Voice.** A paper read before the Franklin Institute, May 16, 1888, by Emile Berliner. Sketches the history and present status of the invention. *Jour. Franklin Institute*, June, 1888.
- Hammers, Steam.** By C. Chomienne, Engineer. Translated from the French. The author has had many years experience in the management of extensive iron works. *Railroad and Engineering Journal* June, *et seq.*, 1888.
- Iron, Pig.** A lecture before the Franklin Institute, by A. E. Outerbridge, on the production of pig iron, including the relations between its physical properties and chemical constituents. *Sci. Am. Supple.*, April 14, 1888.
- . *Wrought.* Tabulated records in detail of results obtained from over 2000 test pieces of wrought irons. *Rept. U. S. Board of Testing*, Vol. I., 1881, pp. 46-91.
- Irrigation in India.** See Agricultural Engineering in India.
- Latimer, Charles, Eulogy upon the Life of.** By W. H. Searles, before the Civil Engineers' Club of Cleveland. *Jour. Assoc. Engin. Soc.*, June, 1888, Vol. VII., pp. 201-207.
- Levee, Davis Crevasse.** By S. F. Lewis, before the American Society of Civil Engineers. Gives details of the break in Davis levee, near New Orleans, and the method adopted in its repair. *Trans. Am. Soc. C. E.*, Oct. 1888, pp. 199-204.
- Locomotive, Express, Wootten, U. P. R. R.** Brief description, with detailed drawings of passenger engines with the Wootten fire-box built for the Union Pacific Railroad. Cylinders, 18 by 26 inches; drivers, 63 inches; weight on drivers, 76,500 pounds; total weight, 118,500 pounds. *R. R. Gazette*, June 15, 1888.

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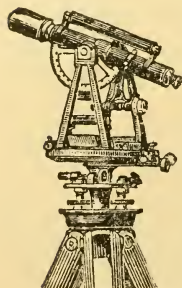
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- Locomotive, Distribution of Steam in the Strong.** By T. W. Dean, before the American Society of Mechanical Engineers. Abstracted, *R. R. Gazette*, May 25, 1888.
- Locomotives. Coupling and Connecting Rods.** A series of papers on the proper design of coupling and connecting rods for locomotives. *Engineer*, May 25 *et seq.* 1888.
- Machine Designing.** By John E. Sweet. A lecture delivered before the Franklin Institute. Illustrated. *Sci. Am. Supple.*, April 28, 1888; abstracted *R. R. Gazette*, June 15, 1888.
- Masonry, Government Specifications for.** Gives the regular specifications for stone work in use in the Government architect's office. *Eng. News*, June 2, 1888.
- Motors for Alternating Currents.** See Electric Motors.
- Oil Burners for Steam Boilers.** Abstract of a series of papers by Herr Busley, of Kiel, a marine engineer, describing the leading or typical devices which have been and are used for burning liquid fuel, under the following classification: 1. Hearth fires. 2. Gas fires. 3. Spray fires. *Railroad and Engineering Journal*, April, May, June, 1888.
- Pavements, Asphalt.** A report by W. P. Rice to the Board of Improvement of Cleveland on the use of Asphalt Pavements. *Engin. and Build. Rec.*, May 26, 1888.
- Pumping Machinery. Types of Hydraulic Pumping Machinery.** By J. T. Fanning. A short historical and descriptive paper, with cut showing an improved form of turbine pumping machinery. *Jour. New Eng. W. Works Assoc.*, Sept., 1886.
- Railroad Signals, Automatic.** Gives a description of the automatic signals in use on the Fitchburg Railroad, Mass. *R. R. Gazette*, June 15, 1888.
- Railroad Construction.** Gives a list of all railroad lines in United States, Canada and Mexico, on which track was laid during 1887, with a two-page map printed in colors, showing track laid from beginning of 1886 to June 15, 1888. *Engin. News*, June 16, 1888. See also Tabulation in *Railroad Gazette*, June 1 and 8, 1888.
- Railroad Location. Field Practice in the West.** By Willard Beahan. A valuable paper on the methods of location from the standpoint of a chief of a locating party. *Jour. Assoc. Engin. Soc.*, June, 1886, Vol. VII., pp. 196-201. *R. R. Gazette*, May 12, 1888.
- Resistance, Compensated Standards of.** See Electrical Resistance.
- Sewers, Construction of, in Madras, India.** By Hormusji Nowrosji. Records some of the construction details of sewers of Black Town, Madras, India. The three sewers have a total length of $5\frac{1}{4}$ miles, varying in diameter from 12 to 30 in. It is on the separate system. *Indian Engineering*, March 31, 1888.
- Steel. Twenty Years of Open Hearth Experience.** By W. E. Kock, before the Engineers' Society of Western Pennsylvania. Traces the development of the open hearth process, and gives much interesting information concerning the use and working of steel. Abstracted *Engin. and Build. Rec.*, May 19, 1888, and *Engr. News*, June 9, 1888.
- Surveys, Exterior Boundary of Townships.** By Z. A. Enos. Discusses whether the exterior boundary line of a township, as first run or as modified by subdivisional lines and corners, is to be regarded the true boundary line. *Rep. Ill. Soc. Engrs. & Surv.*, 1888, pp. 90-101.
- . See Railroad Location.
- Test Pieces, Incorrectly Proportioned.** A paper showing the errors in estimating results of tension tests due to the use of incorrectly proportioned test pieces. *Rep. U. S. Board of Testing*, Vol. I., pp. 91-104.
- Trestles. Standard Plans.** Gives plans and details of the standard pile trestle in use on the Chicago, Burlington & Northern Railroad. *Engin. News*, June 9, 1888.
- Water Meters.** A discussion covering 11 pages in the *Jour. New Eng. W. Works Association* for September, 1886.
- Water Supply. Capacity of Drainage Ground in Time of Drought.** A study of the Capacity of the Sudbury and Lake Cochituate water-sheds in time of drought. By Desmond FitzGerald. Reprinted in *Jour. New Eng. W. Works Assoc.*, December, 1887.

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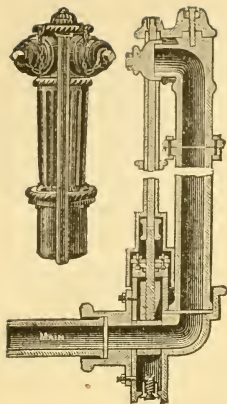
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- Water-Works, Lawrence, Mass.** A paper by H. W. Rogers. Illustrated. *Jour. New Eng. W. Works Assoc.*, Dec., 1886.
- , *Liverpool, Quarry.* Gives method of quarrying, blasting, flagging and dressing stone, with total cost, for the Liverpool water-works. *Engineering*, March 30, 1888.
- , *Nagpur, India.* Gives a general description of the works for supplying Nagpur, India, with 15 gallons per capita per diem by a gravity system; also contains much information in regard to rainfall, evaporation, discharge and consumption. *Indian Engineering*, March 10 *et seq.*, 1888.
- , *Ware, Mass.* A well and reservoir system for town of 6,000. A paper by F. L. Fuller, giving a full description and cost. *Jour. New Eng. W. Works Assn.*, Sept., 1887.
- Wells, Artesian.** By T. B. Comstock. An abstract of a paper discussing the conditions which must exist for artesian wells. *Rpt. Ill. Soc. Engrs. & Surv.*, 1888, pp. 120-126.
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VOL. XLI.

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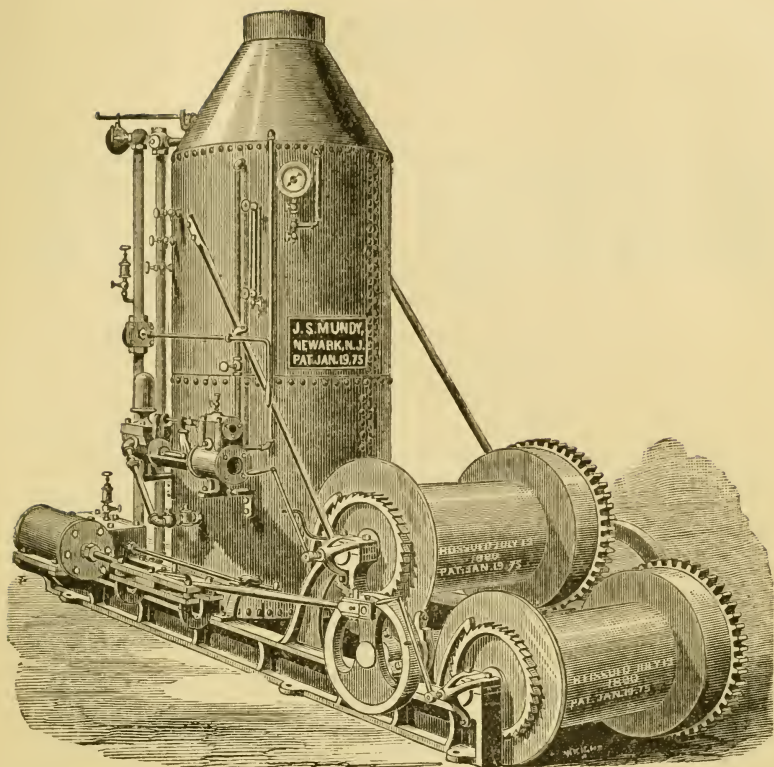
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THE METHODS AND APPARATUS USED IN THE RECENT TEST OF WATER METERS AT BOSTON.

BY L. FREDERICK RICE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read April 18, 1888.]

In March, 1887, L. Frederick Rice, Civil Engineer, Charles Carr, Mechanical Engineer, and Nathaniel M. Lowe, Mechanical Expert, were requested by the Boston Water Board to undertake, in its behalf, the examination of such water meters as might be designated, "making a full test and report upon their merits."

The Water Board gave no instructions as to methods of procedure, and imposed no restrictions whatever; assuming only that the scheme of work would be carefully considered before adoption, and asking that such scheme, when determined upon, should be submitted to the board for its approval. The desire was expressed that the examination of meters should be "so far public as to leave no room for question."

In compliance with this desire, the work of the Testing Commission has been done in a room open to whoever chose to visit it for the purpose of witnessing the operations. Fortunate in securing skillful assistants, the Commission has been able to dispense with the volunteer aid so kindly proffered at an early stage of its labors.

In the belief that a description of the work done and the methods and apparatus used in these experiments may be of interest to members of the Society and possibly to others, this paper has been prepared.

Before deciding upon the course of action to be adopted in making the desired tests, the Commission carefully considered the functions of a water meter,—the forces by which it is actuated,—the circumstances under which it acts and the various causes modifying its action.

A water meter is an instrument used for measuring water as it passes through a pipe, and recording the quantity measured in such manner as to form the basis of charges for the use of the water.

The *perfect* meter will make an absolutely accurate *measurement*, uninfluenced by variations of pressure, or rate of flow,—guiltless of leakage and undeterred by frictional or other resistance,—and it will honestly and

truly *register* and declare the exact amount of such measurement, regardless of remissness or only partial performance of duty on the part of the measuring apparatus.

It will continue to do this for an indefinite period,—in gritty as well as in clear water,—with the temperature of the air or water below 32° or above 212° Fahr., or at any intermediate point,—located in the attic or in the coal bin,—set level or plumb or in any other position that carelessness or ignorance or malice can devise; and although busy and scheming brains work tirelessly over the problem of how to “beat the meter,” it will never be caught napping nor fail in its duty.

We have it from good authority that “the perfect meter has not yet been found.”

It might, perhaps, be classed with the philosopher’s stone and perpetual motion; tantalizing, but unattainable.

But why seek a standard of measure of greater value than the commodity dealt in? Why should time and money be expended in the search for absolute accuracy in measuring *water*, whose value in this market, sold by meter, is two cents per 100 gallons or 15 cents per 100 cubic feet,—equal to \$1.50 per 1,000 cubic feet, or \$45 per 30,000 cubic feet, which is an average yearly duty for a $\frac{3}{4}$ -inch meter in this city.

Forty-five dollars per year is $12\frac{1}{2}$ cents per day for 617 gallons, or one cent apiece for every person who uses 50 gallons of water daily. If the meter by which this water is to be measured should vary 5 per cent. from perfect accuracy, what would be the yearly cost of the error? \$24! Fifty-six cents in the quarterly bill!

The Testing Commission endeavored to ascertain wherein the various meters submitted to it failed of perfection, and the degree of such failure; also if such failure was the result of faults of design, or of workmanship, or of material; and also whether any means could be discovered whereby the action of any meter could be improved.

Water is usually distributed through cities and towns by means of a system of pipes, through which it is forced by pumps, or flows by gravitation from some source more or less elevated. If the water in any pipe system is at rest, a gauge applied at any point thereof, would indicate the weight of a column of water whose height equaled the difference in elevation between the gauge and the supply reservoir; or the pressure maintained by the pump. This is designated the “static pressure or head.”

If, by drafts upon a pipe system, a movement of the water therein is caused, the velocity of such movement creates certain resistances, by reason of friction of the water upon the interior surface of the pipes, or the obstruction afforded by abrupt changes of direction or of size. In overcoming these resistances, a portion of the static pressure is expended, and water would be delivered upon the premises of a consumer at an effective pressure, which would be the *static pressure* reduced by the sum of such *resistances*, and by the actual withdrawal of a portion of the water for the supply of other consumers.

This may be considered as the initial pressure for any consumer, *not* what is due to the height of the reservoir or pressure at the pump which furnishes the supply.

The usual practice is for individual water takers to bring water from the street main into their premises through a small pipe. In the majority of instances, the inlet or supply pipe for dwelling houses is $\frac{3}{8}$ inch or $\frac{1}{2}$ inch in diameter, and varies in length from perhaps 20 feet to 100 feet, or even more.

At the end of the supply pipe the meter is placed, usually in the cellar or basement of a building, where it will be more or less protected from frost. But when the water is passing through the meter, the velocity of flow through the *supply* pipe creates resistances *therein*, by which the pressure under which the meter operates (as would be indicated by a gauge placed close to its inlet), is not that due to the *elevation of the reservoir*, nor yet the *effective pressure in the main* in front of the premises, but the latter, *reduced* by the resistances encountered in the *supply pipe*.

If the moving parts of a meter are closely fitted, the accuracy of fit causes a resistance to motion—a true friction.

When a valve of a meter is under a heavy pressure its movement develops friction by which resistance is offered to the motion of the piston. If the water passages in a meter are long, or crooked, or of small diameter, or constricted at certain points, or if the ports are small, all these offer resistances to the passage of water through the *meter*. All these meter resistances serve to consume a portion of the pressure at the *inlet* of the meter.

From the outlet of the meter, the house distributing pipe, usually of $\frac{1}{2}$ -inch, $\frac{3}{8}$ -inch, $\frac{1}{2}$ inch and $\frac{3}{4}$ -inch diameter, conveys the water by routes more or less tortuous, to convenient points throughout the house, and it is drawn therefrom through faucets which are situated at various heights above the meter, and which may be opened partially or to their full capacity, as may be desired.

We thus encounter additional resistance in the distributing pipes, and a part of the pressure remaining at the *outlet* of the meter is taken up in overcoming them.

When water finally reaches the faucet, the volume or discharge varies with the amount that the faucet is opened, which is, of course, at the consumer's option.

Or, expressed more concisely, the *initial pressure* at the entrance to the premises of any consumer is reduced by certain resistances met with in the *inlet pipe*, caused by friction upon the interior surface thereof (dependent upon its diameter and length),—changes of direction (dependent upon the number of such changes and their degree and abruptness),—and changes of size. (dependent upon their number and degree).

The initial pressure is further reduced by the resistance offered by the *meter* (dependent upon the intricacy and size of the water passages, and the friction of its moving parts).

The initial pressure is still further reduced by resistances encountered in the *outlet pipe* (dependent upon its size, length, changes of direction and size, etc., and also upon the elevation of the orifice of discharge above the meter).

The quantity of water obtainable by the consumer is that which the *effective pressure* (or what is left of the initial pressure after the various

reductions above enumerated) *can force through the orifice of discharge, and this* is finally modified by the size and conformation of that orifice, or by the variety of faucet employed and its degree of opening.

Hence it is of vital importance to a *consumer* of water that his piping, meter and fixtures shall be so designed and constructed that the sum of these reductions shall be a minimum.

If the moving parts of a meter fit loosely, there will be more or less leakage of water by the piston or through the valves without communicating motion to the measuring members, and consequently without registration, or with a registration in favor of the consumer.

It is therefore of importance to *water boards*, or any *persons who have water to sell*, that the leakage without registration should be a minimum.

It is of importance to *both buyer and seller* that the details of the action of a meter under any and all circumstances and conditions, shall be *known quantities* and not mere assumptions.

Influenced by the foregoing considerations, the Testing Commission determined to reproduce, as far as possible, the conditions of actual practice, and to test each meter under various initial pressures, combined with such resistances to a free discharge of water as are liable to be encountered,—to note carefully all the data of each experiment and keep a full record of all the results obtained and phenomena observed,—and to make such notes and record a part of the report, in order that the conclusions of the Commission might be verified or disproved by any interested parties.

It was decided that after the accuracy of each meter had been tested, it should be subjected to a trial to determine the effect of continued usage upon the accuracy and also the durability of the meter,—and that examination should finally be made of the interior, to determine its condition and to enable a study to be made of the nature and quality of the materials used in the construction,—the workmanship,—the design, both in general and in detail,—the cost, both of maintenance and originally,—the space occupied,—the weight,—and the facilities for adjustment and repairing; in short to try every meter under all practicable conditions, and make such examination and study as would disclose the cause of, and if possible the remedy for, any erratic action that might be indicated by the record, and show whether an apparent defect was capable of correction or removal either by the use of different material, better workmanship or change of proportions of parts,—or if it was due to the inherent fault or inadequacy of the design of the meter.

Later it was decided to supplement the records and report based thereon, by appending photographs showing the external appearance of each meter tested, and also such portions of the interiors as should seem desirable to exhibit the effects of the experiments.

The meters placed in the hands of the Commission for testing were mostly of 1-inch and $\frac{3}{4}$ -inch capacity. In a few instances, where none of the smaller size could be obtained, samples of $\frac{5}{8}$ -inch capacity were substituted. The Commission decided to fully try the $\frac{3}{4}$ and $\frac{5}{8}$ -inch meters of all the various kinds submitted, before passing to the larger size. Subsequently, in view of the lapse of time occasioned by the multiplicity

of meters to be tested, all trial of the 1-inch meters was omitted. Still it is believed that the experiments made were sufficiently extended, and the study of the construction and action of the various meters sufficiently comprehensive to justify conclusions applicable not only to the particular samples tested, but to the *types* of meters to which the samples belong.

THE TESTING APPARATUS

was devised by the Commission, and was erected in a room constructed in the southerly end of the basement of the Massachusetts Charitable Mechanic Association Building.

The testing-room was about 65 feet long by 24 feet wide, lighted by windows on one side, and having a door at one end, secured by a lock to which only the members of the Testing Commission had keys.

Adjoining the testing-room, and accessible by a passage through it, was a small room, about 12 by 13 feet, used by the Commission as an office, and for the storage of records of the tests, and of meters while not undergoing examination.

During the entire period occupied by the tests and the preparation of the report, no person whatever had access to the testing room, or to any of the meters or testing apparatus, except in the presence of one or more members of the Testing Commission; and none but members or employés of the Commission had any connection with the operation of testing or access to the records thereof.

The testing-room was divided lengthwise by a railing into two equal parts. The testing apparatus was erected in the inner one, and the outer one opened to the public at all times when testing was in progress, —the rail preventing unauthorized access to the meters or the apparatus, or the records, while enabling visitors to see and hear all of the operations of the tests.

Watchmen were employed, both by day and by night, to see that the premises occupied were not intruded upon, —the watchman's station being outside the testing room, but provided with facilities for observing the entire interior.

A 6-inch cast-iron pipe was laid from the large water-main in the street to the testing-room. This was controlled by a gate at each end, and in the experiments herein described served in place of the street main in actual practice.

To this, within the testing-room, was attached a $\frac{3}{4}$ -inch lead pipe, about 50 feet long, laid horizontally and controlled by a gate at its junction with the larger pipe.

Another pipe of 1 inch diameter was provided for use when testing meters of that size. It proved useful in experiments where the rate of flow was so slight that the resistance from friction was inappreciable, and could, therefore, be ignored.

The apparatus, therefore, allowed the simultaneous trial of two meters.

The 1-inch and $\frac{3}{4}$ -inch pipes took the place of the *service* pipes in practice, and to the inner end of either was attached the meter under trial, controlled by gates close to inlet and outlet. The outlet of the meter was connected with several vertical pipes of various lengths, but each governed by a gate at its lower end, so as to be manipulated from the

testing-room. These pipes, of $\frac{3}{4}$ inch diameter, represented the *distributing pipes* in an ordinary building, and, by means of the gates, water could be discharged at various heights above the meter; while, by the attachment of disks, with orifices of various sizes, to the upper ends of the pipes, the size of the stream discharged was at the option of the experimenter.

The sizes of the orifices used in these experiments were $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, .15, .05, .04, .03 and .02 inch.

In this manner it was easy to observe the effect produced upon a meter by drawing water from faucets located in the several stories of a building;—the amount of opening of the faucet being under the control of the operator, who could thus cause water to be discharged at points $7\frac{1}{2}$, 22, 36, and 51 feet above, or at the level of the meter.

The water thus discharged, falling into a funnel-shaped receiver, was conveyed by a pipe back to the testing room, into a tank mounted on a Howe platform scale, where its amount was determined *by weight*. When filled, the tank could be emptied into a drain pipe directly connected with the street sewer.

In order to observe the effect of light initial pressures upon the performance of the meters, as in the case of a building located at an elevation but slightly less than that of the reservoir from which the supply comes, or where the supply is nearly exhausted by other consumers before reaching the one under consideration, tanks were located over the testing-room at elevations of 7, 26, 40, 54 and 84 feet above the meter, with suitable connecting pipes, thus enabling meters to be tried under pressure of the water from either of these tanks in the manner already described.

The pipes from these tanks to the meters were one inch in diameter.

Gauges were placed at the end of the 6-inch pipe, and at the inlet and outlet to the meter.

Plate 1 shows the general arrangement of the testing apparatus as before described, and is self explanatory.

It will be seen that with eight sizes of discharge orifice, and each of these tried at each of five elevations, the apparatus permits the observance of the performance of a meter under forty different conditions; and if all six sources of initial pressure be used, one hundred and eighty-four varieties of condition may be obtained.

Identical results would doubtless be obtained in many instances, and as the record of these, especially if made in the case of 35 meters, would be very bulky, and the time consumed in the experiments very great, it was decided to omit a portion, and the report gives the record of but forty-one varieties of condition.

TEST FOR ACCURACY.

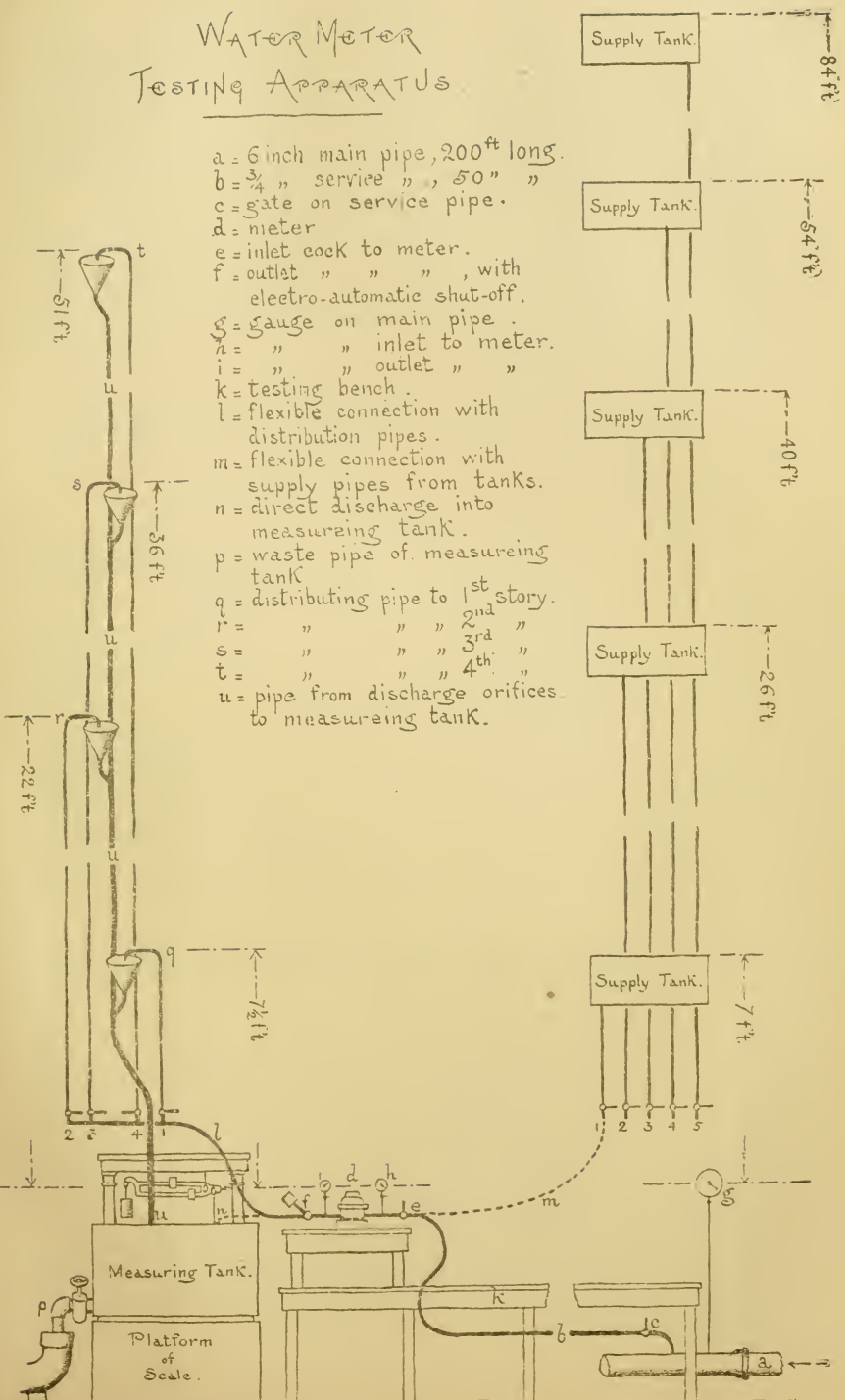
In testing the accuracy of a meter, water was passed through it until a predetermined number of cubic feet had flowed into the measuring tank. The flow was then stopped by closing the gate at the outlet of the meter, and the amount as indicated by the register of the meter compared with that actually received into the tank.

The variation between these is the "error" of the meter.

The register may indicate the passage of *more* water than is received

WATER METER TESTING APPARATUS

- a = 6 inch main pipe, 200^{ft} long.
- b = $\frac{3}{4}$ " service " , 50 " "
- c = gate on service pipe.
- d = meter
- e = inlet cock to meter.
- f = outlet " " " , with electro-automatic shut-off.
- g = gauge on main pipe.
- h = " " inlet to meter.
- i = " " outlet " "
- k = testing bench.
- l = flexible connection with distribution pipes.
- m = flexible connection with supply pipes from tanks.
- n = direct discharge into measuring tank.
- p = waste pipe of measuring tank
- q = distributing pipe to 1st story.
- r = " " " 2nd "
- s = " " " 3rd "
- t = " " " 4th "
- u = pipe from discharge orifices to measuring tank.



into the tank ; in which case the meter is said to "over register," or to register "against the consumer." For convenience, in the records of these trials, over-registration is indicated by the sign +.

When the register indicates the passage of *less* water than the measurement shows, the meter "under registers," or "registers in favor of the consumer," and in such cases the sign — is used in the records.

The "error" is given as a percentage of the *actual* flow.

The quantity of water received into the measuring tank being determined by weighing, it is evident that failure to shut off the water exactly simultaneously with the rising of the scale beam, would give an erroneous result, and that such failure would be very liable to occur if the shutting off be done by hand.

It was therefore decided to use an

ELECTRIC AUTOMATIC SHUT-OFF.

The details of this attachment having been perfected, and its construction completed, connection was subsequently made with a stop-clock and an alarm bell.

A photograph of the entire device is appended to the report.

The action of the shut-off is as follows :

At the outlet of the meter under trial is placed a full-way Chapman balance valve, of new and improved pattern, which fully closes with a quarter turn of the handle, actuated by a small lead weight.

When in operation the handle is held down by a detent, connected with the armature of an electro-magnet, the wires from which, passing to the platform scale on which is the measuring tank for the reception of the water from the meter, from a closed circuit.

Upon the reception into the tank of the predetermined quantity of water, the scale beam rises, breaking the circuit,—the handle of the valve is released, and the valve instantaneously closed by the falling weight. Simultaneously, the clock, previously set at zero, and which has been put in motion by the opening of the valve, is stopped,—while the bell calls the attendants to note the duration of the experiment, read the register of the meter and the gauges, and perform any other duties that may be required.

In thus determining the quantity of water by weighing, it was assumed that one cubic foot of water weighed $62\frac{1}{2}$ pounds, and that the scale beam, being weighted for 625 pounds, would indicate when 10 cubic feet had been received into the tank.

This assumption is not absolutely correct, since the weight of a cubic foot of water varies with the temperature, which was therefore observed and recorded, and a correction made when the "error" was calculated.

The temperature of the water during the tests varied from 46 degrees to 76 degrees Fahrenheit, corresponding to a variation in the weight of 10 cubic feet of water of from 622.2 lbs. to 623.75 lbs., and the number of cubic feet, as indicated by the scale, was therefore corrected by multiplying by a factor which varied from 1.002 to 1.0045.

This automatic shut-off proved to be of great value in facilitating the work of testing, since it entirely eliminated the possibility of error by reason of imperfect manipulation of the shut-off or hurried reading or comparison of watches.

RECORD OF WATER METER TEST. BOSTON WATER BOARD.

1987

RECORD OF WATER																								
Date of Expt.	Meter Used.	Source of Supply.	Gauge.			H'd Lost (Friction).			Diameter.			Duration of Trial.		Meter Reading.		Temp. of Water.	Tank Measure.	Time needed to pass 10 C.F.	Flow per minute.	Ratio, Meter to Tank.	Error of Meter.	Remarks.		
			In Main.	Inlet Pipe.	Outlet Pipe.	Inlet Pipe.	Outlet Pipe.	Outlet above Meter.	Inlet Pipe.	Outlet Pipe.	Outlet.	h.	m.	s.	Begin.								End.	C.F.
May 3		City Pipe.	46	13	3	0	33	10	3	0	11	5	4	2	11	100	100.1	34.1	100.1	101.2	0.99	Free disk, not tank.		
	No 48073																							

When trying a meter under a very slow delivery of water, requiring considerable time for a single experiment, the apparatus could be set in operation at the close of a day's work, and then locked up and left to do its duty unattended during the night and tell the whole story in the morning.

When trying a meter under back pressure, or when discharging from an orifice at some elevation above the meter, the pipe to the orifice was filled with water before adjusting the scale, and on the completion of the run, when the tank, having received the weight of water for which it was adjusted, stopped further flow through the meter, the water then remaining in the return pipe was allowed to run into the tank and weighed, and its weight added to that at which the scale had been set.

RECORD OF ACCURACY TESTS. (SEE PLATE 2.)

In the record, as appended to and forming a portion of the report, the following data are given :

The name and number of the meter experimented on.

The source and elevation of the supply of water.

The date of each experiment.

The gauge-reading on main pipe.

The gauge-reading of inlet to meter (working).

The gauge-reading at outlet to meter (working).

The gauge-reading at outlet to meter (at rest).

The difference between the first and second of these gauge-readings represents the frictional resistance of the inlet or service pipe, between the main and the meter.

The difference between the second and third gauge-readings shows the resistance or loss of head due to the meter under trial.

The difference between the third and fourth gauge-readings shows the resistance offered by the house distribution-pipe and discharging-faucet.

The height of outlet above the meter is given, and corresponds to the fourth gauge-reading.

The diameters of the inlet-pipe, outlet-pipe and orifice of discharge are also recorded.

Record is then made of the duration of the trial, showing the hours, minutes and seconds occupied by each run made, and the aggregate—the latter expressed (for convenience of calculation) in minutes and decimals thereof.

Meter-readings, at the beginning and end of each run, and cubic feet of flow indicated for each.

Temperature of the water.

Tank-measure (in cubic feet) as indicated by the scale, and same corrected for temperature.

Ratio between the meter-reading and the corrected tank-measure, from which is deduced the percentage of error of meter, + or -, or over-registration or under-registration.

From the corrected tank-measure and duration of trial are deduced the actual time needed to pass 10 cubic feet;

Actual flow per minute, in cubic feet;

Percentage of increase of time due to use of meter as compared with a

pipe without meter, and percentage of decrease of delivery due to use of meter, showing the amount of reduction of capacity.

These last two items are not recorded unless exceeding 5 per cent.

Upon these record sheets are also noted all details of experiments, such as stoppages, breakages, repairs, repetitions, etc.

TEST FOR DURABILITY.

The object of this test was to determine the effect of continued use upon the accuracy of meters, as ascertained in the series of trials just described, and designated the first test for accuracy.

The 6-inch main, supplying the water for the experiments, was continued into the testing-room, 50 feet beyond the point where the supply-pipes for the trial of single meters branched off.

This main was tapped and 24 one-inch lead branch pipes, spaced at equal distances over the entire length, inserted. Each of these branches was controlled by a stop cock. A long bench was erected over the main pipe, and a drain pipe, with branch openings opposite the stop-cocks, laid beside the main, under the bench; and at the farther end of the testing room, near the measuring tanks, joined the main drain from thence to the street sewer.

This admitted of a number of meters being placed upon the bench, each connected with a 1-inch supply pipe, and each discharging through a separate 1-inch lead waste pipe with stop cock, into the drain.

All the meters that had passed through the first accuracy test—24 in number—were placed upon the bench and run simultaneously and continuously until their respective registers indicated that about 75,000 cubic feet of water had passed through each. This quantity is equal to about two years' average duty of meters of $\frac{3}{4}$ -inch capacity, as shown by the records of the Boston Water Board.

It having been questioned whether the meters located at different points along the main would be subject to the same pressure of water, calculations were made to determine the difference of pressure, if any, between the two extremities and intermediate points. These calculations indicated that the discharge of 99.3 cubic feet of water per minute, which was the rate when all the meters were running, would cause such a velocity of flow in the 6-inch pipe from the street main to the location of the first meter, as would develop a friction considerably reducing the initial or static pressure,—but that the further reduction between the first and last meters would be but $\frac{4}{10}$ pound,—showing that there was no practical difference in the pressures upon the different meters.

To ascertain if observation confirmed the calculation, gauges were placed at each end and in the middle of the bench. These being read, water was then turned on to the first meter, and the gauges again read. The remaining meters were then successively set in motion until all were running; the gauges being read as each was added. The last meter was then shut off, and then the others, successively, until all were again quiescent; still reading the gauges in the same manner. At no time was there any perceptible difference between the three gauges, but the pressure indicated by each steadily diminished as the meters were successively set in motion, and rose again as they were turned off, until on the completion of the experiment the initial pressure of 46 pounds was reached;

completely confirming the calculations, and showing that the various meters were tried under precisely similar conditions.

The previous trials showed a marked difference in the resistance to flow offered by the various meters, and also in the volume of the discharge in a given time. Those offering the least resistance were the first to reach the conclusion of this trial. As soon as any meter showed by its register that the 75,000 cubic feet of water had passed through it, it was stopped by closing its waste-cock, but the pressure was left upon the meters until all had completed the trial. The time required to pass the 75,000 cubic feet varied from nine to eighteen days.

Ten days after thus shutting off each meter, trial was made to ascertain its relative liability to obstruction by reason of sediment within the meters or by corrosion, or adhesion of parts, or from any other cause, during the period of rest. The waste cock was opened very gradually and without shock, and note made of the degree of opening before water flowed,—the rate of flow before movement of register began,—and the variation from accuracy after starting of register.

The record of the durability trial shows the register reading of each meter three times each day,—the time of completion of trial, or failure, with cause thereof,—and notes of any occurrence of interest, peculiarities or cessation of action, etc., and the causes of same if ascertained.

SECOND TEST FOR ACCURACY.

This trial was made to ascertain the effect of continued usage upon the accuracy of a meter, and was made in a similar manner, and with the same apparatus as the first test, but under a smaller variety of conditions,

The record sheets are in a similar form.

By comparison of the records of the two tests of accuracy, the effect of the wear of the test of durability becomes apparent.

To facilitate such comparison, sheets have been prepared, on which is given a Graphic Representation of Meter Error under all the various conditions of the two tests for accuracy. These show, at a glance, for each meter and each experiment therewith, both before and after the test for durability, the actual delivery of water (as measured in a tank), and the percentage of Error of Registration, either over or under; also the maximum and minimum percentage of error; also their mean and the range between them: the average percentage of error, and the effect of wear upon the range and the average; also the general retarding effect of each meter as compared with a pipe without meter. Plate 3 is a sample sheet of the Graphical Representation of Meter Error, compiled from Plate 2 and other record sheets.

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of the test gives, in figures, for all the meters tried, the same information that is conveyed by the Graphic Representation, together with further data relative to the meters tested, such as cost, space occupied, weight, etc.

The flow of water through *pipes without meters*, under all the conditions of these tests, was determined, and is recorded, and has been used in calculating the diminution of flow entailed by the use of the various meters.

SPECIAL EXAMINATION.

After the conclusion of the second accuracy test, the various meters were separately opened, their action studied and their condition examined, after which photographs were made showing the exteriors of the meters, and also all broken or worn portions of the interiors.

In discussing individual meters in the report, the operation of each is fully described.

It was the original intention of the Testing Commission to test the meters under higher pressures after the conclusion of the experiments with the pressure obtained from the city pipes and from reservoirs of low elevation.

For this purpose the connection between the street main and the testing apparatus was to be closed, and a pump applied directly to the 6-inch pipe within the testing-room, by means of which any desired pressure could be obtained, in the same manner as in the Holly or other direct pumping systems.

But the number of meters submitted for testing was so greatly in excess of the anticipations of the Water Board as to so prolong the trials that it became necessary to restrict their scope. It was, therefore, decided not to attempt any tests under the higher pressures.

In addition to these limitations, the tests conducted by the Commission dealt only with the soft, clear water supplied to Boston, and it is not assumed that they will be of use in determining the durability or continued efficiency of meters used with water in which sand or other cutting or scouring material is suspended, or which holds in solution corrosive matter.

But it is believed that the records of these tests give data which will be of value to makers and buyers of meters in considering the utility of any proposed device for measuring water under pressure and recording such measurement.

THE TESTS AND THEIR RECORDS.

In all the operations of testing and recording great care has been observed to insure accuracy.

One or more of the members of the Testing Commission has been present, and taken part in every detail, no matter how trivial.

During the bench trials, the clocks, scales, gauges, meter registers and thermometers were in all instances independently read and separately recorded by two or more observers. These notes have been carefully compared by two persons, and entered upon the record sheets, which form a part of the report. All the calculations based upon these notes have been made by two or three computers working independently of each other, and all the entries upon the record sheets are by the same hand, carefully compared and checked by one or two revisers. Typographical errors being absolutely avoided by photo-lithographing the record sheets, it is believed that the report of the performance of the meters in these tests is substantially correct, and that it shows the action of the meters under circumstances that are identical with those attending their actual use. No two meters in actual service are subjected to precisely the same treatment, and that of any individual meter is constantly changing. No meter, in the trials here reported, has had any usage that it is not liable to encounter at any time.

NOTES ON THE WATER METER SYSTEM OF PROVIDENCE,
R. I.—FROM 1872 TO 1887 INCLUSIVE.

BY EDMUND B. WESTON, MEMBER OF THE BOSTON SOCIETY OF CIVIL
ENGINEERS.

[Read April 18, 1888.]

I have arranged my subject into the following six divisions, in such a manner as will best answer, in a general way, the most important questions that are frequently asked relative to the water meter system of Providence :

1. The consumption of water in Providence ; the force who read and repair the meters ; and general notes and conclusions.
2. Method of testing meters.
3. Manner of setting meters.
4. Different kinds of meters in use.
5. Expense of maintaining meters.
6. Nature of the work charged to the meter maintenance account.

CONSUMPTION OF WATER, ETC., ETC.

During the year 1887 the daily average consumption of water of the city of Providence, and consumers on 15 miles of distribution pipe outside of the city limits, as well as the State institutions in Cranston, was 4,940,000 gallons. This is equivalent to 39 gallons per capita, considering the total population of the city, and the number of consumers supplied in the suburbs.

The average daily consumption per tap has been during the last six years. viz. : 1882, 354 gallons ; 1883, 379 gallons ; 1884, 356 gallons ; 1885, 395 gallons ; 1886, 384 gallons ; and 1887, 376 gallons.

Fifty-eight per cent. of the water services in Providence, had meters on them on December 31, 1887.

Experience has led me to the conclusion that the use of meters prevents an extravagant use of water, while at the same time it does not prevent the quantity being used which is essential for good health and necessary domestic purposes ; as the consumers who pay for the actual quantity of water that they use are much more liable to see that their plumbing and fixtures are kept in good condition, than are those who pay at fixture rates.

I will mention one of the many cases that my attention has been called to, in substantiation of this conclusion, as an illustration. Several years ago, a bill of \$117 for one year's consumption of water was presented to a citizen of Providence, and as his bills had not averaged more than \$17 previous to that time, he naturally questioned it, and intimated that his meter must be wrong, as he was positive that he had not used anywhere near the amount of water that was specified in the bill. The meter was disconnected and tested, and found to register correctly ; he then had a plumber examine his piping, who reported that it was in good order. The final result was that the Water Board sent two of their own employés to make an investigation, who after spending considerable time discovered a hole in a $\frac{3}{4}$ -inch lead pipe that was laid under a green-house

floor, through which a large quantity of water was flowing, that at once accounted for the unusually large use. Now, in all probability, if this supply had not been metered, as to all outward appearances the plumbing about the premises was in the best condition, this large waste of water might have gone on for years.

If meters had not been used in Providence, there is not any doubt but what the consumption of water since 1871, the time when the Pawtuxet water was first introduced into the city, would have been much larger than it has been: consequently considerable expense has been saved, with regard to fuel, wear and tear of pumping machinery, and possibly a large outlay for additional pumping plant, etc., that might have been required.

The minimum water-rate in Providence, when meters are set, is \$10 per annum. At the present time (December 31, 1887), about thirty-seven per cent. of the consumers who take their supply through meters pay at the minimum rate.

It is generally considered advantageous for consumers, whose bills at the usual fixture rates would exceed \$14 or \$15 per annum, to have meters set, the \$4 or \$5 above the minimum amount being allowed for interest on the outlay, and the maintenance of the meters.

The meter system in Providence seems to give satisfaction, both to the city and the consumers who have meters. The meters are the property of the consumers, who are obliged to purchase such as are approved by the Water Department, whose employes set them and make all necessary repairs, etc., at the consumer's expense. It is optional with the consumers whether they will have their services metered or not; but the Water Board reserve the right to set meters, at their own expense, whenever they deem it advisable; this is rarely done, however, except in cases where there seems to be a large or extravagant use of water.

The Water Board permanently employs three men who read all the meters quarterly, which takes on the average about five weeks during each quarter; and do all the necessary water fixture inspection that is required, as well as other work connected with meters, etc., in the office. Probably, if meters were not used, more than three inspectors would be required to examine fixtures, etc.

When meters get out of order, or fail to register altogether, and the consumers have not previously notified the water department of the fact, it is easily detected by these men every quarter, by being obvious at the time the meters are read, or by comparing the amounts registered with the amounts registered during previous quarters, which is always done if there is the slightest question of doubt as to the registration of the meters; consequently the city sustains very little loss, if any, when meters are found to be out of order at the end of a quarter, as the amount for the quarter is estimated from previous quarterly readings. Meters very rarely fail to register during the first quarter that they are in service, but when they do, as the water bills are payable yearly, with the exception of those of the large consumers, which are collected quarterly, there is generally very little difficulty in estimating the quarterly deficiency.

There is a shop connected with the Water Department, which is fitted up expressly for repairing, testing, and storing meters, etc. Three men,

the total sum of whose salaries is \$2,900 per annum, set on the average 490 new meters per year, in addition to making the repairs on all the meters, the average number of which is about 600 per year, as well as disconnecting and resetting them (the original castings, etc., being obtained from the manufacturers). These men also examine all the elevator counters, open and close such service stops as may be required to be attended to when the service pipe clerk is not within call, make out the returns of work done, keep the detail meter repair accounts, and perform other miscellaneous work that may arise.

I have been informed that the only trial it was deemed necessary under the circumstances to give the first meters that were set in Providence was an ordinary tank test, as the Water Commissioners wished to set meters as soon as possible after water was first introduced into the city. The inadequacy of a test of this kind, I think, will be demonstrated by the facts that will be presented as I proceed. It should be remembered, however, that meters which have iron bodies or parts that water can come in contact with, are placed at a great disadvantage on this account alone in Providence, as corrosive action commences to take place in a marked degree upon the iron almost immediately after they are set.

Since the year 1877 there have been tested on the Providence Water-Works, under the direction of the City Engineer, more than twenty different kinds of meters at the request of their inventors or manufacturers, in addition to those meters which are now in actual service in Providence. I shall not mention these meters that have been tried and not adopted, however, as it has not been customary in Providence to disclose the results of their tests, other than to their individual inventors or manufacturers.

If the design of a meter is not obviously impracticable at first sight, it is generally very difficult to form a correct opinion as to its merits until after it has been subjected to one or two years' trial (and it cannot always be done then), for the reason that a meter whose principle and mechanism at a preliminary examination may appear to be commendable, will frequently show in actual service defects where and when they are least expected. The water service pipes in Providence, are sized according to the requirements of the applicants, who, in each instance, fill out and sign an application, which states for what purpose the water is to be used, and the nature and number of the fixtures on the premises to be supplied. The applicants are allowed to have smaller services than their fixtures call for, provided they make the request in writing upon their applications, as well as larger by paying the additional expense of laying, etc.; but in each instance the meter must be the same size as the service pipe (or at least not smaller). This rule, with regard to meters, may appear to be rather arbitrary at first thought, but it works on the whole very well and saves much debate and controversy.

METHOD OF TESTING METERS IN PROVIDENCE.

Before being accepted by the Water Department, the different kind of meters that are under consideration are subjected to several tests. The first test is for accuracy, on streams varying in diameter from $\frac{1}{100}$ to $\frac{1}{2}$ inch, or to the size of the outlet of the meters, the actual amount of water that flows through the meters being weighed.

The second test is for durability, which is accomplished by setting the meter on constant service, in a room prepared for the purpose, in which are laid pipes that lead from the high to the low service, so that a continuous stream of water is obtained without waste, under about 150 feet head. At different periods during this test, if it is thought best, the meters are disconnected and tested again for accuracy on the streams before mentioned. This test for durability is concluded on $\frac{3}{4}$ to 1 inch meters, when from one hundred thousand to four hundred thousand cubic feet of water has passed through each meter. A final test for accuracy is then made, and if the meter registers satisfactorily and an examination shows that they are not badly worn, or have not broken down during the test, they are subjected to the third test, which is made by placing them on regular domestic service ; then at the end of six months or a year or more, they are once more tested for accuracy and once more thoroughly examined, and if the result proves satisfactory they are generally allowed to be set by the Water Department.

After a class of meter has been accepted by the Water Department, each individual meter before being set is tested for accuracy under ordinary pressure on a one-quarter inch stream, and if the error of its registration is not more than two per cent., they are allowed to be set. If the error is more than two per cent. the meters are returned to the manufacturers. A description of the plant used for testing meters (which was first set up during the year 1878), and the general method of testing is as follows : A four-inch pipe, etc., brings the water from a 24-inch main to the bench in the meter room where the meters are tested. A short piece of two-inch flexible pipe is connected to this four-inch pipe. The meter to be tested is placed upon the bench, and the inlet connected to the flexible pipe by a coupling. To the outlet of the meter another short piece of flexible pipe is also connected in the same manner, which terminates in a one-inch brass pipe, which is suspended above the bench on a stanchion, and is so arranged that it can swing in any direction. A one-inch faucet is connected to the outlet end of this brass pipe, which is so arranged, that disks, which have holes of different sizes bored in them, can be fastened into it, so that the size of the stream can be enlarged or reduced at will. At a convenient distance from the test bench an iron tank is located upon an accurate pair of scales. This tank is capable of holding about 600 gallons.

When the meter is connected, and the proper sized disk has been placed in the faucet, on the brass pipe, it is closed, the water is turned on from the four-inch pipe, the faucet swung over the tank and opened, and the water allowed to flow until the hand on the ten-foot dial of the meter registers zero. The faucet is then closed, and the water in the tank weighed. The faucet is then again opened, and after ten cubic feet of water, as registered on the meter dial, has flowed into the tank, it is once more closed, and the water again weighed, and the difference between the weight of water in the tank when the dial registered at zero, and the weight at ten, is referred to a table, on which is shown opposite to figures corresponding to this difference the percentage of error, if any, in the registration of the meter. The test for accuracy is generally concluded, by running a second stream through the meter

while the largest disk is connected ($\frac{1}{2}$ inch for $\frac{5}{8}$ inch), and opening and closing the faucet 100 times.

Pressure gauges are connected to the four-inch and to the one-inch brass pipe, and the tank has an outlet into a sewer, which can be opened or closed by a valve. The tables for determining the error of registration of the meters are based on a temperature of seventy degrees, but if it is considered necessary, the temperature of the water is taken during the test, and if it is more or less than seventy degrees an allowance is made, the table giving a co-efficient for the purpose. A difference of temperature of ten degrees one way or the other, however, will not generally affect the final result more than one-tenth of one per cent.

A new $\frac{5}{8}$ -inch meter, if properly constructed, ought not to show an error, when subjected to a tank test for the first time, of more than two per cent., under 70 pounds pressure, on streams of $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{3}{4}$ inch in diameter, and not more than five per cent. on a $\frac{3}{4}$ -inch stream. Under the same pressure it should be able to allow 100,000 cubic feet or more of water to flow through it, at a rate of at least 1,200 cubic feet per twenty-four hours, without showing an increase of error, when again tested for accuracy on the streams before mentioned, from $\frac{1}{8}$ to $\frac{1}{2}$ inch, of more than two per cent. It should also be capable, when new, to work under 70 pounds pressure on ordinary domestic service four years, registering at least 50,000 cubic feet, and not show an increase of error at the end of that time of more than two per cent. on streams from $\frac{1}{8}$ to $\frac{1}{2}$ inch, inclusive.

A good design of meter on ordinary domestic service ought to run on the average at least six years before being repaired, and ought to be serviceable (possibly having to be repaired more or less), for at least ten years.

MANNER OF SETTING METERS IN PROVIDENCE.

Meters are set when possible in cellars, and as near to the stopcock, which is located just inside of the cellar wall, as possible; thereby allowing for the attachment of lateral pipes beyond the meter. Service pipes generally run into dwellings under their cellar floors; in these cases, a small pit is usually dug in which the meter is set, and packed with mineral wool or plasterers' hair as a precaution against freezing. The walls of these pits are generally built of brick, laid in cement, the natural earth being used for their bottoms, in order to let any moisture that may get into them leach away. For the smaller sizes of meters, their average dimensions are about $2\frac{1}{2}$ feet along, $1\frac{1}{2}$ feet wide, and from 1 to $1\frac{1}{2}$ feet deep. When the service pipes enter buildings above their cellar floors, the meters are usually located on shelves fastened to the cellar walls, and boxed up, and packed as before mentioned, unless the cellars are sufficiently heated to prevent the meters from freezing. The pits in the majority of cases are built, and the shelves put up by the plumbers at the expense of the proprietors.

It is always deemed advisable to set meters as low as convenient, in order that the water may be drained from them when it is shut off at the stop-cocks on cold nights by the proprietors (the stop-cocks each having a waste).

Meters are in some cases, it being impossible to avoid it, set outside of

buildings in pits. In these cases the best kinds also have brick walls, the natural earth being used for their bottoms for the reasons before mentioned. In building the walls of these outside pits, a number of bricks are set in each case so as to project into the interior, about half way between the top and bottom, in order to hold up a horizontal wooden partition that is placed upon them; the space between the partition and the cover, which is at the surface of the ground, and is made of wood or iron, being usually filled with hay to prevent the meter from freezing. The average dimensions for the smaller sizes of meters, are about 3 feet square and 5 feet deep. The tops of these pits are arranged so as to prevent surface water from flowing into them. The outside pits, like those of the inside of buildings, are usually constructed by agents of the proprietors at their expense. Proprietors sometimes, however, have their pits constructed of wood in order to save first cost, but this generally results in being more expensive in the end.

If the precautions that I have mentioned, relative to protecting meters, are taken, they are very rarely injured by the cold weather.

DIFFERENT KINDS OF METERS IN USE.

On December 31, 1887, the following water meters were in use in Providence :

KIND.	Size.							Total...
	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	1 in.	$1\frac{1}{2}$ in.	2 in.	3 in.	4 in.	
Union piston.....	2,963	580	138	46	6	.....	.....	3,733
Union rotary	1	.....	22	26	3	7	3	62
Crown.....	3,057	488	123	47	15	3	3	3,736
Fales, Jencks & Sons	15	11	2	.....	.....	.....	.....	28
Worthington	61	1	.....	.....	1	.....	1	64
	6,097	1,080	285	119	25	10	7	7,623

The first meters were set in Providence in the year 1872, which was the year following the first introduction of Pawtuxet water into the city.

The Union piston meter was the first kind used. During the first year (1872) 589 of them were set. There were 3,733 in use on December 31, 1887, which is the largest number that ever were in use in Providence. The average number that have been set per year, during the last seven years, is 16. The bodies of these meters, for sizes below $1\frac{1}{2}$ inches, are of bronze, with iron heads; and for sizes of $1\frac{1}{2}$ inches and upwards they are of iron, brass lined, with iron heads.

The second kind of meter used was the Worthington, which was first set in 1873. During this year 115 of them were set. The largest number that were ever in use in Providence is 163, which was in the year 1876. On December 31, 1887, there were 64 of them in use. The bodies of these meters are of iron.

The third kind of meter used was the Fales, Jencks & Sons', which was first set in 1874. During this year 19 of them were set. The largest number that were ever in use in Providence is 580, which was in the

year 1877. On December 31, 1837, there were 28 of them in service. The bodies of these meters are of bronze.

The fourth kind of meter used was the Union rotary, which was first set in 1877. During this year five of them were set. The largest number that were ever in use in Providence is 63. On December 31, 1887, there were 62 of them in service. The bodies of these meters, for sizes below two inches, are of bronze; and for sizes of two inches and upwards, they are of iron, bronze lined.

The fifth kind of meter used was the Crown, which was first set in 1880. During this year 52 of them were set. The largest number that ever were in use in Providence is 3,736, which was on December 31, 1887. The average number that have been set per year, during the last seven years, is 533. The bodies of these meters, for sizes below three inches, are of bronze; and for sizes of three inches and upwards, they are of iron.

APPROXIMATE COST OF MAINTAINING WATER METERS IN PROVIDENCE.

The detail meter maintenance account was commenced during the year 1878, but has only been worked up to 1886 inclusive, therefore the figures of cost that I shall mention, will not include the cost of maintaining any of the different kinds of meters previous to 1878 (they all having been in service, with the exception of the Crown), or the cost of maintaining them since 1886.

The total cost of maintaining the Crown meters during the entire period that they have been in service in Providence (six years), is, not including eleven meters that have been condemned, \$1,462.00, and including the condemned meters, \$1,659.00. The average cost per year for each time that a Crown meter was repaired or examined, etc., is, not including the condemned meters, \$2.85, and including the condemned meters, \$3 17. The total average cost of maintenance, from 1881 to 1886 inclusive, for each Crown meter in use on December 31, 1886, is, not including the condemned meters, 45 cents, and including the condemned meters, 51 cents; also the average cost per year, from 1881 to 1886 inclusive, for maintaining each Crown meter in use during each year, is, not including the condemned meters, 23 cents, and including the condemned meters, 26 cents. All of the other kinds of meters were in service in Providence, before the detail maintenance account was commenced, and with the exception of the Union piston meters, and the Union rotary meters (which are nearly all large sized meters and are generally set on elevator or motor supplies), are gradually being taken out of service, condemned, and replaced by other kinds of meters, I will only mention individually, in addition to the Crown, the cost of maintaining the Union piston meters.

The total cost of maintaining the Union piston meters in Providence, from 1878 to 1886 inclusive, is, not including 121 meters that have been condemned, \$13,685, and including the condemned meters, \$16,671. The average cost per year, for each time that a Union piston meter was repaired or examined, etc., is, not including the condemned meters, \$3.10, and including the condemned meters, \$3.67. The total average cost of maintenance from 1878 to 1886 inclusive, for each Union piston meter in use on December 31, 1886, is, not including the condemned meters, \$3.74, and including the condemned meters, \$4.75; also the average cost per year, from 1878 to 1886 inclusive, for maintaining each Union piston

piston meter in use during each year, is, not including the condemned meters, 44 cents and including the condemned meters, 53 cents.

In Providence the manufacturers of the Crown meters bear the expense of all the repairs, due to defects in the meters, that are made on them during the first three years that they are in service; and the manufacturers of the Union piston meters bear the expense of all the repairs, due to defects in the meters, that are made on them during the first year that they are in service. This expense was included in working up the preceding figures relating to the cost of maintaining the Crown and Union piston meters, as I wished to ascertain the entire cost of maintenance, without reference as to who bore the expense.

Included in the preceding figures, relating to the cost of maintaining the Crown and Union piston meters, are several charges which are not due to any fault of the meters themselves, the most important of which are those of repairing frozen meters. I have not as yet had time to investigate this side of the question as thoroughly as I would wish; but I shall not be very far out of the way in saying that the total cost of maintaining the Crown meters, not including the condemned and frozen meters, is \$806, or 45 per cent. less than the preceding figures relating to the Crown meters, and including the condemned and not the frozen meters, \$1,003, or 40 per cent. less; and the average cost per year for each time a Crown meter was repaired or examined, etc., not including the condemned and frozen meters, is \$1.95, or 32 per cent. less, and including the condemned and not the frozen meters, \$2.36, or 26 per cent. less. Under the same conditions the total cost of maintaining the Union piston meters not including the condemned and frozen meters, is \$12,398, or nine per cent. less than the preceding figures relating to the Union piston meters, and including the condemned and not the frozen meters, \$15,404, or eight per cent. less; and the average cost per year for each time that a Union piston meter was repaired or examined, etc., not including the condemned and frozen meters, is \$2.89, or seven per cent. less, and including the condemned and not the frozen meters, \$3.51, or five per cent. less.

A GENERAL CLASSIFICATION OF THE NATURE OF THE WORK CHARGED, FROM 1881 TO 1886 INCLUSIVE, TO THE MAINTENANCE ACCOUNT OF THE DIFFERENT KINDS OF WATER METERS USED IN PROVIDENCE.

For the Union Piston Meters.

	Times.		Times.
Yokes worn.....	54	Dials clouded.....	194
Shafts worn.....	705	Glasses broken.....	88
Cranks worn.....	8	Covers broken.....	9
Piston connections sprung.....	6	Clock work out of order.....	50
Shafts broken.....	13	Worn.....	431
Shafts bent.....	6	Rusted at heads.....	551
Cylinders indented.....	17	Frozen.....	193
Piston worn.....	19	Surface water.....	88
Piston sprung.....	12	Leaked at stuffing box.....	123
Piston bound.....	14	Leaked at heads.....	22
Stem gears worn.....	32	Nuts loose.....	200
Valves worn.....	10	Packings blown out.....	19
Did not register.....	11	Solder in meters.....	6
Examined.....	262	Cylinders burst.....	7
Miscellaneous.....	99	Condemned.....	69

For the Worthington Piston Meters.

	Times.		Times.
Spindles bound.....	156	Miscellaneous.....	39
Leaked at spindle.....	17	Condemned.....	72
Rusted.....	69		

For the Fales, Jencks & Sons' Blade Meters.

	Times.		Times.
Blades bound, etc.....	988	Worked hard.....	23
Frozen.....	76	Rings blown off.....	10
Leaked at stuffing-boxes.....	45	Did not register.....	14
Leaked at rings.....	9	Rust in meter.....	13
Clock work broken off.....	10	Miscellaneous.....	36
Clock work out of order.....	19	Condemned.....	441

For the Union Rotary Piston Meters.

	Times.		Times.
Rusty.....	9	Leaked at stuffing-boxes.....	7
Pistons.....	10	Glasses broken.....	5
Shafts worn.....	8	Floats bottomed.....	19
Worn.....	9	Dials clouded.....	5
Caps worn.....	6	Miscellaneous.....	21
Obstructions in meters.....	6	Condemned.....	3
Frozen.....	6		

For the Crown Rotary Piston Meters.

Which is the total, from the year that they were first introduced in Providence. The other meters, it must be remembered, had been repaired more or less, before the detail repair account was commenced.

	Times.		Times.
Frozen.....	98	Clockwork out of order.....	27
Hot water.....	48	Dials clouded.....	5
Leaked at stuffing-boxes.....	59	Leaked at couplings.....	8
Piston spindles broken.....	45	Pistons broken.....	5
Packings blown out.....	18	Examined.....	63
Glasses broken.....	19	Miscellaneous.....	69
Obstructions in meters.....	36	Condemned.....	11
Rust in meters.....	14		

The total cost, from 1878 to 1886 inclusive, of maintaining all the different kinds of meters in use in Providence, is, not including 678 meters that have been condemned, \$19,910, and including the condemned meters, \$38,184. The total average cost of maintenance, from 1878 to 1886, inclusive, for each meter in use on December 31, 1886, is, not including the condemned meters, \$2.79, and including the condemned meters, \$5.35; also, the average cost per year, from 1878 to 1886 inclusive, for maintaining each meter in use during each year, is, not including the condemned meters, 44 cents. and including the condemned meters, 78 cents.

The terms used in the preceding classification, are those used by the men who repaired or examined the meters. I have not attempted to correct them, technically or otherwise.

The items specified by the word miscellaneous, are the class that has not occurred individually five times.

THE PRALL SYSTEM OF DISTRIBUTING HEAT AND POWER FROM CENTRAL STATIONS.

BY E. D. MEIER, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read May 2, 1888.]

Heat is the condition of all life and the foundation of all power. These facts, so clear to the modern engineer, were foreshadowed by the imaginative Greek who invented the myth of Prometheus, that demigod who snatched from Olympus the living fire which was to enable mortal man to become even as the gods themselves. They were the living truths underlying the fire or sun worship of the Parsee race. In this

sense the mechanical engineer may lay claim to a spiritual ancestry far antedating that of the proudest monarchs of the world.

We now know, what they darkly felt or imagined, that the sun is, for us at least, the source of all power and the upholder of all life. Not only does he lift up millions upon millions of foot-pounds of energy in the vapors which he raises from the sea to feed the water powers of the highlands of our continents, not only does he direct and limit the forces of the winds which still continue to do so much of the world's work; but we know that ages ago with beneficent profusion he stored up for us in the coal measures a limitless supply of force, which we can at will liberate from its long imprisonment and turn to our uses. To-day this antediluvian supply determines by its location and condition where the great hives of modern industry shall be planted. But we must modestly confess that we have not yet learned the A B C of economy in the use of this great gift of nature.

If we will put aside those facts and statements based on the best foreign or the best Eastern coals, and confine ourselves to what lies nearest at hand, which is, of course, the problem for us to solve, we find that :

The best possibilities in our average Illinois coal are the liberation of 11,580 heat units from each pound of this fuel consumed. We have theoretically necessary to give us one horse-power per hour 2,565 heat units. Hence one pound of coal burned per hour should give us $4\frac{1}{2}$ horse-power. But we find that our best steam plants, with high pressure engines of the Corliss or an equally economical type, coupled with the best boilers, require three pounds of coal for each horse-power per hour, which is equal to $13\frac{1}{2}$ times as much fuel as it should take theoretically. And this may be placed as for our locality the best present possibility in practice, which can only be reached in large plants, where both the engineer in charge and the firemen at the boilers are considered, taught, and paid as skilled laborers. In most smaller plants where a cheap boiler and cheap engine, pipes poorly covered (or perhaps not covered at all) are handled by underpaid, and consequently unskillful or careless men, from eight to eleven pounds of coal are used per horse-power per hour, which is from 36 to 50 times as much as theoretically necessary, and from $2\frac{3}{4}$ to $3\frac{3}{4}$ times as much coal as would be used in plants attaining the practical minimum above stated. But I know of cases where the record shows a consumption of 80 times the theoretical quantity, or six times the quantity of fuel for each hour's run that is actually used in the best class of plants before described. Now since the best types of engines and the best types of boilers, the best types of heaters, and all other appliances cost very much more per unit of power for small plants than for large ones, and since the higher grade of intelligence, in what is one of the highest and most useful branches of manual skill, can only be had for proportionately good pay, it is clear that we cannot expect to develop anything like the economy aforesaid in small plants scattered all over the city, under sidewalks or up in garrets, etc. Furthermore, the principal danger about the steam plants will always be located in the boiler room. And you cannot but regard it as a great mistake that the good old rule which insisted on placing the boil-

ers entirely outside of factory buildings is utterly disregarded in the smaller and larger plants scattered about populous cities for such purposes as heating, cooking, running elevators, printing presses, sewing machines, electric light plants, etc. A recent report of a board of experts consisting of Profs. R. W. Raymond and Geo. Plimpton, and Mr. C. C. Martin, C. E., refers to this matter as "the growing danger from steam boilers of all sizes distributed in buildings and under sidewalks, and employed in running elevators, dynamos, printing presses, and other machinery. That destructive accidents from this source have hitherto been few is a gratifying circumstance, which must not be permitted to obscure the fact that the danger is constantly increasing with the number of such boilers and with the growing age of those now in use."

Add to this the danger from conflagrations in the overheating of flues entirely inadequate to the work they are called upon to perform; the cost of bringing in coal and carrying out ashes to and from places narrow, dark and scarcely accessible, and the dirt accompanying this transportation. Consider further the smoke and soot, and worse still the invisible gases of combustion, which vitiate the air in rooms in which numbers of men, women and children spend their days in labor, and even perceptibly affect the very atmosphere of the streets, and the fact that all these evils grow with the greater concentration of the best part of our population, *i. e.*, the workers, in districts where the height of buildings constantly increases with unchanged width of streets. We have then reasons enough to account for the many attempts which have been made to concentrate the work of producing this heat-energy in certain central stations, near the fuel supply and more or less remote from the localities where it is to be utilized. Pittsburgh's phenomenal and almost magical transformation by its natural gas supply, has necessarily directed our thoughts to the substitution of a gaseous fuel, flowing in constant supply in underground mains under the streets, and distributed right and left alike to manufactories, office buildings and private residences. There are hundreds of gas producers either seeking for recognition or actively at work on this problem. At the outset it behooves the engineer to inquire into the possible or probable limitations of such a system. The example of the gas light companies teaches us that even with low pressure in the mains, leaks are constant and unavoidable. Increase enormously the quantity of gas required, and we must either use very much larger, or a greater number of pipes, or resort to pipes as strong and joints as carefully and securely made as those which gave the Philadelphia Co. in Pittsburgh its great success. Pittsburgh has not yet eliminated natural gas explosions from its weekly history, although they may no longer create a sensation. But the necessity of the expensive, because thorough, methods of the company aforesaid is acknowledged, and to such methods alone can we look for the prevention of gas explosions. Whether the minor leakage along such lines causing impregnation of the soil, corrosion of the lead water pipes, or of the electric insulators, and possible vitiation of the atmosphere sufficient to intensify if not to create epidemics, may not in course of time show even natural gas to be a not unmixed blessing, we cannot here discuss. The precautions,

dimensions and mechanical contrivances found necessary in Pittsburgh's excellent system will no doubt limit the supplying of manufactured fuel gas to certain districts where the quantities are great and the necessities imperative. Furthermore the fuel gas solves but the first half of the problem in furnishing the fuel in the exact condition in which it can best be burned, while the great multitude of small consumers, who will always create the bulk of the demand, require not this raw material but the manufactured product, *i. e.*, the heat energy itself ready at hand in the smallest sub-division. I am, therefore, convinced that fuel gas when its use becomes general will be distributed direct to certain larger plants where the best appliances and the most skillful handling can be had, and that from such the live heat energy will be portioned out to the army of small consumers.

Large central steam plants have been and are being successfully operated in favorable localities, and where they have been originally designed and built with great scientific knowledge and practical skill. Where these have been wanting they have failed, always will fail and ought to fail. They naturally require very large pipes and joints difficult to make and more difficult to keep tight, because not constantly accessible. Steam being very elastic cannot be pumped or forced by mechanical means, but finds its own velocity at the expense of loss of pressure, loss of temperature and continuous condensation. From these result the always annoying and sometimes dangerous "water hammers" and wet steam and other kindred evils for the consumer. And these evils increase proportionately the larger the demand for heat or power made upon the pipes, so that invariably when most needed the service is least good.

Hot water, i. e., very hot water, a great deal hotter than any one has ever seen it, next offers its solution. Water having the greatest capacity for heat of any known substance (except certain chemical solutions valueless for practical purposes) has been chosen as the measure of specific heat for all substances. A cubic foot of water at 400 deg. F. carries 22,000 heat units, while a cubic foot of steam at the same temperature carries but 682 heat units, *i. e.*, but 1-32d as much. There is no difficulty in forcing water, under any pressure, through pipes at a speed of ten feet per second. Steam can be made to travel much faster, but many practical considerations limit the safe speed in long pipes to about 60 feet per second. While no hydraulic engineer would hesitate at pressures in water from 400 to even 1,000 pounds per square inch, I doubt if any steam engineer would have the hardihood to propose supplying a large and complicated net-work of underground pipes with steam at much more than at 100 pounds pressure. If we assume 125 pounds gauge pressure (equal to 140 pounds absolute) as the present practical limit, we find that our cubic foot of steam carries 376 heat units, or about 1-60th of the quantity held by one cubic foot of water at 400 degrees F. From practical considerations such as these we may then deduce the statement that a steam plant should have five to ten times the pipe area of a hot-water plant, *i. e.*, its pipes must have from $2\frac{1}{4}$ to $3\frac{1}{4}$ times the diameter of those of the hot-water system.

While there have been earlier systems of hot water supply, limited in

extent, and some are to this day running with eminent success, the Prall system for supplying heat and power from central stations, is, I believe, the first which has been put successfully into service on a large or metropolitan scale. A short description of the system will show where it differs from its precursors in methods and appliances.

We have first a central station with its batteries of boilers of a safety pattern, *i. e.*, constructed with comparatively small shells and small tubes, all with internal pressure, so that all parts of the elastic steel structure shall be in tension, and with a circulation so positive that differences of expansion, which would be caused by differences of temperature, are eliminated. Next, in addition to the ordinary feed pump, we have a pump or a number of pumps for taking the water from the boilers and driving it through a series of street mains carefully wrapped with non-conductors, and placed in an accessible conduit of brick or wood, each of which mains constitutes a complete loop, so that its further end returns directly to the boilers, the egress and ingress nozzles being so placed as to increase the natural circulation of the water in the boiler. At distances prescribed by street and alley crossings, but limited to lengths of 100 to 150 feet are placed expansion joints, being simply castings, bolted to one end of each section, and to a solid block of foundation, into the further end of which enters through proper stuffing-boxes a phosphor-bronze sleeve which forms the initial end of the next section of pipe. These castings are so arranged as to take at the same time the expansion joints of a return main to be afterwards described, and the cross connections for the intersecting street or alley. Close to them are also placed stop valves to make it possible to cut out one section at a time for repairs while temporarily supplying the district beyond through the next street main, which thus for the time becomes a by-pass pipe.

In each section is also placed a check valve, being a simple spherical enlargement of the pipe, in which a heavy metal ball is so located that it can roll into and close the conical mouth of the pipe to either side as soon as the fixed maximum speed of the water is exceeded. In case of accident, therefore, or of malicious injury, the two nearest check valves would shut off the injured section, so that the leakage would simply have the effect of flooding the conduit to a depth of a few inches with water, while the steam formed therefrom would be rapidly dissipated at a very low pressure. An explosion cannot occur here, since, in the opinion of the best experts, a good-sized rupture even of the shell of a boiler, when entirely under the water line, will rarely cause an explosion, since water alone, no matter at what pressure, will not readily attain a dangerous velocity. In the case of our pipe we have cooling influences at hand to reduce the effect of such ruptures, while, in the case of a boiler, additional furnace heat is constantly adding to the pent-up energy. At intervals of about 20 feet a coupling is placed, which at the same time is utilized for supplying service boxes placed at the sidewalk. These couplings have special threads, having the peculiarity that the base of the thread is conical, *i. e.*, runs out, while the crown of the thread is sharp and cylindrical. By this means the weakening of the pipe is diffused over a considerable length, so that experiments have shown it possible to preserve 97 per cent. of the full strength of the pipe.

Furthermore, this form of thread can be so forced into the coupling as to actually bed the metal of the pipe into it and make an absolutely tight joint, even under the test pressure of 1,500 pounds.

All pipes before being laid are tested to 4,000 pounds pressure; a certain percentage of them, however, are tested to rupture, which generally requires over 12,000 pounds. Each section when laid is again tested to 1,500 pounds, and made tight under this pressure, and finally the whole main is tested to 1,500 pounds per square inch. The entire supply pipe or force main rests on rollers supported on cast-iron brackets about fifteen feet apart. The same bracket holds under its arched base a return pipe of double the diameter of the pressure main, which rests and rolls on a small iron trolley supported on the base plate, the whole being bolted down to a brick pier. This larger return pipe also forms a complete loop under the pressure main; it has similar joints, couplings and expansion sleeves. The whole pipe system, after being tested, is wrapped with an asbestos covering, over which is secured a layer of asbestos cloth painted with water-proof paint. Over this, with a liberal air space between, is placed a brick arch, outside of same another air space, and still another brick arch, the outside of which is covered with some water-proof cement. The Board of Experts before referred to found the loss in temperature of a four-inch hot-water main in Boston to be only four degrees for a length of nearly two miles, and that at a minimum speed of the circulating current of one and a half feet per second. The claim of the Boston Company that their entire loss by radiation will not be more than two and a half per cent. on the average therefore seems well founded.

From each coupling in the hot main a one-inch pipe runs to the service box located at or under the sidewalk, where by means of a tee it branches into three openings, each closed by an asbestos-packed cock. From this point to the inside of the house wall generally, a distance of less than ten feet, a small copper supply pipe runs to the converter, copper being used to enable the steam fitters to run their pipe in any direction around obstructions to the point where the converter is most conveniently located. These pipes run generally from one-eighth to three-eighths inches in diameter, one inch being a maximum. The converter is simply a steel vessel taking the place, in the house, of the steam dome, which is not required on the boilers at the station. The small copper service pipe terminates in a pressure-reducing valve screwed by a short nipple against the converter. These valves are controlled very nicely and accurately by electricity. To the top of the converter the steam pipe either for power or for the ordinary steam system of the house is attached, being of the same dimensions as if attached to a local boiler. Each converter is further supplied with a steam gauge to show the pressure at which it is set; at its bottom it connects through a return pipe into the service box, and from that back into the return main. As a further precaution a pop safety valve is placed in a horizontal position at the bottom of the converter, so that in case of excess of pressure by a failure of the reducing valve to do its work, the water can be discharged through the safety valve into the return system. Where ordinary steam-heating plants exist in a house the steam pipe from the top of the converter is simply connected with the same, the connection with the boiler

being broken. The same applies to the connection of the system to an existing power plant. Where furnaces or indirect heating or ventilating systems are to be replaced a coil of pipes is substituted, either directly from the main with hot water or from the converter with steam. For cooking a range is used in which a net-work of these small hot-water pipes is placed so as to give a constant temperature, sufficient for cooking, baking, etc.; in fact, every operation except broiling, and ranging from 350 to 400 degrees F. It will be seen that by using two converters we may first extract from the hot water sufficient steam at 70 or 80 pounds pressure to drive the power plant of a building, and from this pass the water into a second converter to furnish a further supply of steam at a very low pressure, which may be supplemented by the exhaust from the engines to heat the entire building in the coldest weather. I have above considered only the difference in economy between large, well regulated power plants, and small, cheap, local ones. When we come to compare the cost of this system with the cost of fuel for domestic heating and cooking purposes we find that only 10 to 15 per cent. of the heat in the coal is there in practice utilized, as against from 50 to 75 per cent. in steam boiler plants. The Boston Heating Company, which has had this system in use on a large scale during the past winter estimates for ordinary city houses about $1\frac{1}{10}$ heat unit per cubic foot per hour. I have found in good examples of steam heating in this city a consumption somewhat larger, but as in my case the buildings were used for offices, where on account of almost constant opening of doors a larger loss of heat may be expected, I believe it to be perfectly safe to figure on 2 heat units per cubic foot per hour as a maximum. Of course, this will be much modified by the circumstances of exposure.

If we consider 5 pounds gauge pressure as ample for steam heating on the average, we find that at this pressure our hot water at 400 degrees F. will give us nearly 20 per cent. of its weight as available steam and still have a large quantity of heat left in the other 80 per cent. for indirect radiation, or for heating water for baths, etc. At the pressure mostly used for pumps, elevators and small engines about city buildings, say, not exceeding 70 pounds, the same water will return us about 10 per cent. of its weight as available steam, the other 90 per cent. being further available for the other purposes above mentioned, and, of course, the exhaust from these engines can be further directly applied for warming, ventilation, etc. Practically then a 4-inch pipe would, at a speed not exceeding 10 feet per second, be able to completely supply 50 average stores of 25 feet frontage, 120 feet depth and three stories of each being heated and each supplied with its own elevator. Since, however, a plant of this kind will always run during the whole 24 hours, and, therefore, the brunt of the fight against cold can be borne by the system during the early morning hours before there is any demand for power, we may reasonably expect to get a result fully 20 per cent. better.

Whenever the plants of heating companies under this Prall system become of sufficient size, a great deal of the water from the return becomes available for condensation at the station, thus reducing the cost of running its own pumps, electric light and fan engines. The water after all its service has been performed, is thoroughly filtered to remove

any grease, grit or dirt it may have picked up in its wanderings, and is then pumped back into the boilers by ordinary feed pumps, passing on through the same pipe and mixing with the water which comes back from the return end of the pressure main. The system has been not inaptly compared by its promoters to the Gulf Stream, which furnishes an example of the great distance to which water can carry heat, thus making the tropical sun of the West Indies exert a genial effect on what would otherwise be the glacial coasts of Northern Europe. When a new main is first put into service, the hot water is pumped through it at a low speed, and this is continued until the conduit and its surroundings are well dried out, and the minimum speed for that main is then fixed by the rule that the last consumer, *i. e.*, the one nearest the station on the return end of the loop, is entitled to a temperature of not less than 390 degrees. When the house connections are afterwards all made, while the inflow of the pipes will be at a much greater rate of speed, as long as the return end of the loop maintains this minimum speed the last consumer will be practically as well served as the first. Each station contains apparatus for measuring and recording temperatures and pressures of the boilers, of the outgoing and incoming main, and of the return main. An inspection of the Boston plant in its every day working must convince the most skeptical that the solution of the heat and power problem of modern municipalities has been found, and that a continuance of the same methods of thoroughness will advance this solution still further, and probably soon fix the limits of such systems in all directions as concisely as they have been fixed for our ordinary gas and water supply. While the great first cost of such a system will in every city limit its first application to the most thickly built-up portion, and therefore to the business section, its advantages will there become so palpably manifest that such central stations will gradually be found supplying the best settled residence districts also, especially since the margin between domestic economy in fuel and that possible in such a station is much greater than that existing between it and ordinary isolated steam power plants in the business section.

One fact bears strong testimony alike to the correctness of the system and the thoroughness with which the chief engineer of the company, Mr. Arthur V. Abbot, C. E., has done his work in every detail of design and execution. As soon as the first two boilers (Heine patent) were put in position a steady circulation of warm water was forced throughout the entire main, the temperature gradually increased up to 380 degrees, and next a solution of potash was pumped into the main and circulated for several days to remove all traces of grease and red-lead. Then this hot potash water was replaced by fresh warm water until no more signs of contamination existed. During about ten days consumed in this manner, the whole of the line was carefully watched as to leakages and the working of the expansion joints. Thereupon house connections were immediately made and heat and power supplied during the entire winter, without an hour's interruption from any cause whatever, during which time eight more boilers were successively placed in service. Parties using the steam testify to its being unusually dry. When snow was on the ground there was no sign of its melting faster over the conduit

than in other parts of the street, except at the man-holes, which are simply covered with two iron plates with an air space between them.

THE WATERWAY BETWEEN LAKE MICHIGAN AND THE MISSISSIPPI BY WAY OF THE ILLINOIS RIVER.

BY ROBT. E. McMATH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 30, 1888.]

Many and various have been the projects for a waterway between the Great Lakes and the river system flowing into the Gulf of Mexico. At a comparatively early date in the history of what was once known as the West, canals were constructed from Lake Erie at Erie, Pa., to the Ohio River at Beaver, Pa.; from Lake Erie at Cleveland, O., to the Ohio River at Marietta, by way of the Muskingum River, and to the Ohio at Portsmouth, at the mouth of the Scioto River; from Lake Erie at Toledo, O., to the Ohio at Evansville, Ind.; from Lake Michigan at Chicago, to the Illinois River at LaSalle, and from Lake Michigan at Green Bay, to the Wisconsin River at Portage, Wis.

All of these canals were, in a sense, the offspring of the Erie Canal of New York, and, considering the time and circumstances of their construction, were creditable exhibitions of enterprise on the part of the builders. That their usefulness has mostly passed is no discredit to those who planned and built them. They served their purpose well while the conditions in view at the time of construction lasted. The conditions existing in 1838 require something different.

Of the several routes by which a waterway connection between lake and river systems is possible, that by way of the Illinois is, beyond comparison, the most favorable, in ease of execution, availability for economical use, and especially as inviting a liberal scale of dimensions. It is the only one by which a connection available for naval use is practicable, and, according to the commercial requirements of to-day, the only one whose value as a route for actual transportation is worthy of serious consideration. The other routes have passed out of mind, and most of them from the maps, but this has never been lost sight of, and now engages more attention than ever before.

By the favor of the Citizens' Association, of Chicago, copies of a brief, prepared by L. E. Cooley, C. E., entitled "Lakes and Gulf Waterway," were recently distributed to the club. That brief covers the history of the existing canal, and of the several projects that have received official consideration, so fully that I have no occasion to go over any of that ground.

Personally I was engaged upon the surveys made of the Illinois River in 1866 and 1867, and I was in local charge of the work done by the United States on that river from 1869 to 1872.

The reports made after the surveys of 1866 and 1867 both favored the canalization of the Illinois River, but the plan presented was not formally approved by Congress or an appropriation made to begin the work. The

chief argument then advanced for the improvement was military and naval necessity, an argument which derived most of its force from some of the incidents of the then recent war of rebellion. As time passed, the force of this argument was lost, and the great cost of the canal part of the project frightened Congress. The State of Illinois began the work by authorizing the construction of a lock and dam at Henry, in 1869, devoting thereto the net revenues of the Illinois and Michigan Canal. The appropriations for river and harbor work that year were made in a lump sum, to be expended at the discretion of the Secretary of War. Out of that appropriation an allotment of \$85,000 was made for work on the Illinois River. I was put in local charge of the work by Gen. J. H. Wilson, with instructions to expend the allotment in dredging the channel of the Illinois River below Henry, so as to prepare a bottom in anticipation of the construction of a dam and lock at Copperas Creek. Literally construed, these instructions would have required me to dredge the channel near Henry to a depth of about five feet, and gradually to diminish the depth as the work progressed down stream. The lower bars, which, by the way, were far the worst obstructions to navigation, would have been merely scalped, doing no good so far as immediate use was concerned. But as dipper dredges were used, which could not work in less than four feet of water, and as the work was mostly done when the river was low, there was of necessity a departure from the instructions, which departure furnished about all the practical value the work ever had. The instructions were subsequently modified to suit the situation, and the contractor was paid for all the useful work he did. After 1869 money was provided, by appropriation, for the improvement of the Illinois, by dredging and wing-dams, without mention of the proposed canalization, so that the work done was in the interest of a low water channel. The methods of dam construction, in which the use of brush was prominent, furnished the types and precedents for the construction of the earlier works on the Mississippi. In fact I came from the Illinois to the Mississippi to do what distinguished engineers said could not be done, build a dam across an important channel of the Mississippi, on a sand foundation, that would not settle indefinitely. It was done, and the possibility of improving the Mississippi thereby demonstrated.

Early in my connection with the Illinois River, I became convinced that the favored plan of improving by locks and dams was not advisable below LaSalle, and I became an advocate of an open channel, deepened so far as necessary by dredging and concentration, but looking to a future increase of volume by water drawn from Lake Michigan. As I had the efficient support of the steamboat interests and the tacit allowance of my superior, Gen. Wilson, the United States did nothing to forward the lock and dam project during my connection with the work. But later it did contribute to the work done by the State of Illinois at Copperas Creek, and afterward it undertook the construction of locks at La Grange and Kampsville. These last named works are not far advanced in actual construction, and in my judgment ought to be abandoned, or at least suspended, until the question of the scale of improvement is finally settled. Now they are included in the estimates submitted each year by the Engineer Department.

It has at all times been admitted that a waterway along this route should be maintained, but there has not been unanimity as to the scale of improvement, and possibly some desire to make it a means of giving advantage to one commercial point over another.

Officially, what is known as the Wilson-Gooding project has been adopted, though nothing has been done which commits the United States or the Engineer Department to the canal part of the project. The plan contemplates a 7-foot navigation, with locks 350 feet long by 75 feet wide. The river bed to be used below Joliet, thence to Lake Michigan by a canal fed from the lake, but the flow restricted to the quantity required to supply the wastes of the canal.

Opposed to this official plan is the Hennepin Canal scheme, which, under the guise of a canal to connect the lake at or near Chicago with the Mississippi at or near Rock Island, is, whether the truth is recognized or not by its advocates, a project to occupy the ground from La-salle to Chicago with a so-called waterway that would bar the construction of a real one. The Hennepin project contemplates a barge canal 80 feet wide at the surface and 7 feet deep, with locks 170 feet long and 30 feet wide. If limited to a canal of these dimensions from the Illinois River at or near Hennepin to the Mississippi at or near Rock Island, this project is not objectionable, even from a St. Louis point of view. But when extended, as its most strenuous advocates always insist it shall be, of the same dimensions to the lake, it is a fraud, and should be opposed by the friends of waterways from all parts of the country, and especially by Chicago. As a branch to the trunk line, to which it is of secondary importance, Hennepin would escape unfavorable criticism, but when it is put forward as the trunk line itself, and as of primary importance, it is antagonistic to all interests (even its own), except those of the railways with which it pretends to compete.

A third plan, alternative to both of those named, covering whatever is of value in both, but going farther and meeting other and greater wants than they provide for, has recently come to the front. But as it has come forward more because of its connection with the drainage necessities of Chicago than of its commercial importance, it has encountered prejudices and inconsiderate opposition.

My purpose in this paper is to discuss, from a St. Louis point of view, this last and grander project in respect to its physical, sanitary, economical and political consequences, in contrast with its only practicable alternative, a navigation canal seven feet deep, with Chicago sewage entirely excluded.

Physical includes the effect on the lakes, on the immediate valley of the Des Plaines and Illinois, and on the Mississippi.

Sanitary embraces the consequences to Chicago, to the towns along the line, and those upon the Mississippi below the Illinois, including considerations of water supply and drainage.

Economical considers the effects upon industries and the movement of commodities.

Political takes account of the relation to defense and the uses of state, also the foreign and domestic influence of the improvement.

DESCRIPTIVE STATEMENT.

The project contemplates, First: A canal from Lake Michigan to the Des Plaines River, Joliet being the objective point, having capacity as a channel to carry a volume of at least 10,000 cubic feet per second, at a velocity consistent with the unimpeded use of the canal for navigation. Said canal to be the outlet for Chicago drainage, the volume being made ample to carry the sewage without objectionable pollution.

Second: The improvement of the Des Plaines and Illinois rivers by a sufficient number of locks and dams, between Lockport and LaSalle, to enable vessels drawing 14 feet to pass at all stages of the rivers. Incidental to the building of the dams and to the increase of volume by a constant quantity, a water power of considerable magnitude will necessarily be created.

Third: The volume of water added to the Illinois will secure a sufficient navigable depth in the open channel, and so render the existing and proposed locks and dams below LaSalle unnecessary. These things being done, what consequences will follow?

PHYSICAL EFFECTS.

Of course, a discussion of the probable effect of withdrawing from lake Michigan, and from the St. Clair, Detroit, and Niagara rivers, of so large a quantity as 10,000 cubic feet per second, and transferring the same to the Illinois and Mississippi rivers, must be largely speculative at this time, but after proper observations and investigations, the questions involved can be definitely answered.

As to the effect upon the lake levels, we know that the discharge through the St. Clair River is approximately 217,000 cubic feet per second, which is the total coming from lakes Superior, Michigan and Huron. As Lake Superior is $20\frac{1}{2}$ feet higher than Lake Huron and connected with it through St. Mary's River, its level cannot be affected by any diversion of the waters of Lake Michigan. Lakes Michigan and Huron are practically at the same level, if not absolutely so, but as the St. Mary's River empties into Lake Huron below the straits of Mackinaw, water from the Superior and Huron basins cannot be drawn to an outlet near the southern end of Lake Michigan, unless the outlet shall first take all the water from the Michigan basin. Lake Michigan has a water area of 26,000 square miles, and a direct watershed of 43,000 square miles, or a total of 69,000 square miles. The U. S. Lake Survey report (Primary Triangulation, etc., page 608), assumes that the Lake Michigan basin furnishes one-third of the water passing Detroit, or about 70,000 cubic feet per second. To be amply safe, I will assume that nine inches of water flows off from the area in dry years (the actual gathering of water in the reservoirs near the sources of the Mississippi is about this quantity), which gives a minimum flow through the Straits of Mackinaw of 45,000 cubic feet per second. To withdraw 10,000 feet per second at the southern end of the lake, therefore, will not stop the outflow through the straits, and since there is no perceptible fall, the lessening of the volume cannot draw down the surface except the two lakes are equally effected. Lake Huron cannot possibly be lowered more than by the trifling quantity required to adjust the slope of the St. Clair River, now only $\frac{1}{2}$

inch to the mile, to the volume diminished by five per cent. Again, the area of the two lakes is 59,400 square miles, and 10,000 feet per second would draw off one foot in 4.45 years, or at the rate of 2.7 inches per year. The conclusion is therefore safe, that the effect will not be noticeable, except as a result of a long series of observations, such as was required to establish the fact of a tide in the lakes. The actual decrease will be but a small fraction of the fluctuations of lake level due to other causes. Hence we may say, that the effect upon the lakes, that is, upon the depth at entrances to harbors and through the St. Clair channel, will be practically nothing. The international question can scarcely be raised, as the work and its immediate effect will lie many miles within our own territory, unless a perceptible lowering can be proven.

From Lake Michigan to Joliet the channel may be wholly artificial, in which case the only question is as to the area of cross-section and gradients; or the bed of the Des Plaines may be utilized for part of the distance, which will make it desirable that the flood waters of the upper Des Plaines be diverted to Lake Michigan. This diversion, if the quantity should be equal to that of the lake water taken into the canal, would leave the flood volume in the river, locally, the same as before, and no physical effect in this particular could be attributed to the works. Chicago's drainage and water supply will require this diversion, which has already been authorized by the Legislature of Illinois. The area whose flood waters will be diverted is about 500 square miles. From the data available, it appears that about one-half of the water coming from this area in extreme floods has always gone to Lake Michigan by the Ogden ditch and overflow through the Mud Lake Valley. The relief of the lower river by the diversion cannot therefore be estimated higher than 5,000 feet per second, or one half of the proposed increment. It must also be borne in mind that the Des Plaines floods do not come at times to add their whole volume to the top of the floods from other tributaries, while the constant increment from the lake will augment the floods from every tributary at all times. Hence we are forced to the conclusion, that increase of flood volume at all points of the Des Plaines and Illinois rivers must be expected.

In considering the effect of an increment to the volume of the rivers, in the absence of observed data I will use estimates, but will take a maximum when dealing with floods and a minimum when discussing results upon channel depths.

At some time, geologically not remote, the Illinois Valley was the outlet of the great lakes, and carried a stream to which the present river bears but an insignificant proportion. The project looks to a partial restoration of the outflow of the lakes to the original channel, and so has no natural obstacles to overcome. The valley, as defined by bluffs, is from one to six miles wide. In some places floods extend from bluff to bluff, but generally they are limited, by high sandy prairies or gravelly terraces, to much narrower limits. These prairies and terraces are the bars of the former river, and furnish the sites for towns, and nearly all the cultivable land of the valley. The river bottoms proper are low and much cut up by shallow lakes and swamps. The river bed is a suc-

cession of deep pools separated by shoals. Some of the pools have the character of lakes, there being no perceptible current. At the shoals the current is decided but not strong. The flowage by the two dams already built does little real damage to land, though large areas are permanently covered by back water. If the scheme under discussion is carried out, the surface will be raised somewhat higher above Peoria than it is by the dams at Henry and Copperas Creek. The pools created by the dams are slowly filling with the *débris* brought in by the tributary creeks.

The capacity of the river bed above Lasalle to carry the increased volume need not be considered now. Since the arrangements will all be artificial, the conveyance of 10,000 feet in addition to the natural flow must be a condition kept in mind when studying the plans of dams and channels. But below Lasalle the natural bed must carry the ordinary flow between banks, and in times of flood the overflows must not practically extend farther or last longer than they do now.

Of the flood discharge of the Illinois, we have no direct measure. Taking differences between gaugings of the Mississippi at Hannibal and Grafton in 1881, the maximum difference of 79,000 cubic feet per second appears to be the greatest discharge of the Illinois in that year, if we neglect the several small tributary streams other than the Illinois. If so, we may assume that the greatest flood at the mouth discharges about 100,000 cubic feet per second. At lowest stage the natural discharge at the mouth was, by measurement, in 1866, about 1,200 cubic feet, which is now increased to about 2,000 by the water pumped at Bridgeport. At Lasalle, I know of no approximation to the flood discharge, except that given by Mr. Cooley, in his testimony before the joint committee of the Illinois Legislature, April 7, 1887, as a "preliminary estimate" of the flood of 1887. He said it was less than 58,000 cubic feet at Ottawa, and at Peru not over 60,000. The height of that flood was 26.4 above the natural low water, taken at 4 feet above the mitre sill of the lower lock at Lasalle. This height of flood is near the extreme known before the dam at Henry was built.

The area naturally tributary to the Illinois at Lasalle is 11,950 square miles; at the mouth the tributary area is 27,000 square miles. Since the contributions to floods per unit of area diminish as area increases, it is probable that the ordinary flood volume at Lasalle is about 50,000 cubic feet per second, but the natural channel cannot carry more than 25,000 or 30,000 at bank full stage. The addition of 10,000 feet at all times may not materially increase the height, but will certainly prolong the duration of overflow. It will also tend to take the river out of its banks oftener than would the natural volume. Against these tendencies, serving to increase floods, we may offset: First—The increased facility to flow, due to the removal of the dams at Henry and Copperas creeks. Second—The effect of channel enlargement, under the wear of a low stage volume increased from 2,000 to 11,000 feet per second. Third—Artificial increase of channel capacity by dredging bars and other work.

It has always been a matter of dispute and litigation whether dams increase the height of floods. They may or may not, according to the facts and circumstances of any particular case. If we bring before our minds

the curves of relation between heights on gauge and volume discharged, it is evident that the origin of the curve, or the level of no discharge, is, for the obstructed stream throughout the range of back-water, at the level of the crest of dam, and for the unobstructed stream at a lower level. The two curves at origin differ, for equal discharges, by the height of back water caused by the dam, and by a function expressing the difference in area due to a rise of one unit at the different heights. This function diminishes rapidly as height increases and practically disappears. The height due to back-water will cease to be perceptible when the flood so completely drowns the dam that no break in the surface is to be found. When this stage is reached the hydraulic conditions are the same as if the dam did not exist. Hence, in cases of comparatively low dams the height of extreme floods is not increased, but for lower stages the height for a given volume is greater with than without a dam. For medium stages in the Illinois there is an assured benefit from the proposed removal of dams to offset the increased volume, especially since the lower of the two dams backs the water to the upper one, consequently there is now some back-water at all stages.

The second set off is much more important, and merits more detailed consideration.

The first effect of adding to the quantity of water in a channel is to raise the level as measured by a gauge. If the supply be constant, there will ensue a new surface slope greater than before; with the new slope comes an increased velocity, greater scouring and conveying power. It is a well established principle of river physics that a river traversing a bed whose material can be moved by the current will always create for itself a channel capable of carrying the normal volume of the stream. If the normal volume be increased, there will certainly be a corresponding increase of channel capacity. If there be no limiting conditions imposed by material of bed, the effort will be to bring the new permanent slope to an equality with the former, or slightly below it. Do such limitations exist in the Illinois? And, if so, can they be overcome?

Considered historically, the channel of the Illinois has deteriorated since it ceased to be the outlet of the lakes, and there is good reason to believe that the process of deterioration has not ended. From Henry to Peoria, and from Copperas Creek to Havana, the width, depth, and absence of current are more like a lake than river. In these reaches certainly the adjustment of bed to volume is not complete. A fivefold increase of low stage volume would arrest the encroachment upon the channel by deposit and vegetation. But it may well be doubted whether the current will be strong enough to enlarge the channel where too small for the increased volume. If it should be strong enough, it might not make such an enlargement as we would wish. We want the increase by bottom scour, not by lateral erosion.

From what we know of the Illinois it is probable that the addition of 10,000 cubic feet per second would at first raise the surface at LaSalle at least 10 feet. The normal fall from LaSalle to the mouth of the Illinois was formerly at low water in the Mississippi about 29 feet, distance 225 miles, giving a mean slope of 0.13 per mile. A 10-foot head rise would make the mean slope 0.17 per mile, but this small increase of slope gives

no clue to the acceleration of velocity or of the increase of abrading and transporting power at the places where work is needed. The matter is not one which can be expressed by formula; we must fall back upon experience, that the channel will ultimately be adjusted to the work it has to do. How long it would take the unassisted river to work out such adjustment is another matter upon which no opinion can be given. If we wish to realize results we must assist the process. Of one thing we may be sure, whatever assistance may be given in the way of hastening the channel enlargement, the reinforced natural forces of the river will maintain until the adjustment is complete.

What then are the possibilities of an enlarged channel? My experience in dredging enables me to speak confidently concerning the material found in the bed of the Illinois.

Some of the shoals are a sandy mud mingled with mussel shells to the depth reached in our dredging. The surface of such bars is well protected by the shells against being washed by the current. Other shoals are composed of a tenacious clay that is practically proof against such currents as the Illinois has or is likely to have. Another class of bars are of recent origin; indeed I have known of their coming into notice as the result of a single heavy rain. The material, in some cases, is the light soil and vegetable humus of the bottoms, in others it is sand and gravel. Of the several classes of shoals the last only present any difficulty in the maintainance of excavated channels, and the difficulty in these cases must be less if the tributary streams discharge their burden into the fuller river and quicker current of the augmented stream, than if into the slow current and dead water caused by the dams. Hence this class of bars furnishes no argument against the proposed form of improvement that is not much stronger when applied to the only alternative plan.

The shelly shoals and the tenacious clays will, in my judgment, require the assistance of dredging. With such assistance there is no limit to the depth attainable except the resources of the government, and willingness to apply them to the work.

SANITARY EFFECTS.

The proposition to create an artificial river and to discharge into it the sewage of a city, which expects to become one of the largest cities of the world, is one to be carefully considered from the sanitary point of view.

Chicago is daily demonstrating its ability to pollute a large body of water to an unbearable degree. Chicago River, within the city limits, has an area of 453.1 acres, of which 110.5 is not seriously polluted; the remainder, 342.6 acres, is more or less charged with sewage. The contents of the more active channels are changed nominally, in periods varying from 30 to 80 hours; but some of the slips cannot be said to come within the feeble circulation that is supposed to renew the water; also the South Fork has no circulation other than that due to the sewage discharge, measured by the water supply, which would renew the contents in about two weeks. Into this body of water the sewage of about 700,000 people is now being discharged. The amount of dry organic matter of human origin is estimated at 122,000 pounds daily. Other sources will probably bring the total amount of putrescible matter up to

400,000 pounds per day. The offensiveness of Chicago River sufficiently accounts for the desire of the city to be rid of the nuisance at any cost; it also fully accounts for the fear of other communities, along the proposed line of drainage, lest the nuisance be transferred to their doors. Bad as the smells are, there is a possibility of worse results than any cognizable by the senses. What may we reasonably expect if the proposed plan is carried out?

It may be well here to call attention to a distinction between offensiveness and unsanitary. A very bad smell may produce nausea at first, but one may become habituated to it and no evil follow. A disease laden exhalation may, on the other hand, not give any warning to sight or smell. Just as is the case with water, it may be so muddy as to be disgusting, and yet be wholesome; or it may be clear and sparkling and be laden with disease germs, or carry a pollution of the filthiest origin. Again, the conditions under which human beings, habituated to filth, can live, and apparently thrive, would be speedily fatal to others more delicately organized. The higher the organization the more sensitive to unfavorable surroundings it becomes. In the interest of that larger statesmanship which looks to the healthy development of generations yet unborn, it is important to solve this drainage problem aright. The quality of the men and women who are to dwell in the valley of the Illinois and lower Mississippi, may depend upon the answer given to the question discussed in this paper.

Regarded in the aspect of offensiveness, the study of the Chicago drainage problem has shown, that a flow in the river equal to 15,000 cubic feet per minute to each 100,000 inhabitants secures a condition that is hardly satisfactory in the Chicago River, a flow of 9,000 per 100,000 produces an intolerable condition. The proposed 10,000 cubic feet per second, or 600,000 per minute, would be 24,000 per 100,000, if the population to be provided for be estimated at 2 500,000.

With such a volume passing through the canal, and a large part of it through the Chicago River, sewage would undoubtedly pass beyond the boundary of the city within 12 hours of its production, consequently before the processes of decomposition can be far enough advanced to produce offensive smells. Hence we may confidently say that the plan will secure the cleansing of Chicago River, and solve the local problem.

But will the harmless condition continue through the canal and river?

First of all we must take note of the fact that the Chicago River is not capable of carrying the proposed volume from the lake to the beginning point of the present canal, nor can it be deepened to the standard of depth proposed, 24 feet, without destroying the tunnels for street traffic at LaSalle and Washington streets. There will have to be a new canal from the lake capable of carrying the greater part of the proposed increment, into which the river must discharge. The volume passing through Chicago River would necessarily be large enough to keep the condition tolerable, and bring the sewage to the main canal in a comparatively fresh state; it would then be diluted with clean water and be started on its way, under circumstances more likely, in my judgment, to secure inoffensiveness than if the whole volume traversed Chicago and received the primary discharge of the sewers.

The decomposition of sewage depends upon oxygen, or, as later biological investigations indicate, upon some forms of bacteria. Doubtless oxygen and these lower forms of life go together. We know that water which has been polluted may be purified so as to be clear, but fish placed in it will drown. The life supporting element has been consumed by the process of decomposition that has taken place and it requires a fresh supply of oxygen. In Chicago River we have an instance of exposure to light and air with no inconsiderable amount of agitation, but no progress toward purification; on the contrary, so far as dilution and aeration now go, the condition becomes worse and worse. Partial decomposition of contained sewage by purifying processes seems to change the whole body of water into sewage, though but a small part has traversed the sewers. A second dilution will bring a fresh supply of bacteria and oxygen.

It again is to be remembered that an indispensable condition will be that all solid matters be kept out of the sewage. Garbage, and, indeed, everything capable of cremation, must, in the near future, be so disposed of by all cities. The slaughter and packing houses of Chicago are already adopting improved processes by which former wastes are utilized, and the city has a garbage furnace in successful operation. I think we may safely say that the greatest concentration of sewage has been reached, and that the exclusion of matters that have heretofore gone into the sewers will materially simplify the question of disposal, and render the effect of dilution more definite.

Decomposition of foecal wastes under the water carriage system must take place. With a proper degree of dilution, we know that this process can go on without offence, and it is believed that the proposed dilution will be sufficient. But there must remain a doubt whether, in the case of typhoid and perhaps other germs, dilution in any practicable proportion will render water once contaminated by sewage safe for drinking. When we know more concerning this branch of the subject, it may be necessary to disinfect the sewage of all towns that discharge into rivers which are the source of domestic water supply to towns below. This is no more applicable to Chicago sewage than to that of St. Louis.

The question before us is hardly one in which absolute safety can be demonstrated; but when we consider relative conditions, the matter is more definite. The sewage of Chicago has for several years been delivered into the Illinois and Michigan canal (in part since 1860, in greater proportion since 1871, and wholly since 1883), and has followed the proposed route: hence we can have the benefit of experience, upon the question of relative conditions, present and proposed.

In 1879 the quantity of water passing through the Illinois and Michigan canal was about 9,000 cubic feet per minute. At Joliet, 33 miles below Bridgeport, the water falling over the dam gave off odors comparable to those arising when a privy vault is being emptied. When the river was frozen a percentage of sewage was discoverable as far as Peoria, 160 miles. The condition was so intolerable that the Legislature required Chicago to erect pumping works, as a condition of being allowed to continue the discharge of sewage into the canal. As a result of an increase of volume to 45,000 cubic feet per minute, sewage, in 1886,

could not be traced farther than Ottawa. We have then a practical demonstration of the efficiency of dilution, an efficiency which must certainly increase in a greater than arithmetical ratio. The present degree of dilution is 1 : 4, sewage to lake water. The proposed dilution, when the population of the metropolitan district shall be 2,500,000, will be 1 : 18. This is a mixture that could not be recommended as a drinking water; but it is vastly better than now. Under present conditions offensive pollution, evident to the senses, can at low water be traced about fifty miles, chemically it is not discoverable eighty-one miles below Bridgeport; but in winter the pollution extends farther. The mean condition is fairly well represented by the following results of analyses made under the State Board of Health, reported at quarterly meeting October 28, 29, 1886.

Locality.	IN 1,000,000 PARTS.		Oxygen used.	Number of analyses.
	Free ammonia.	Albuminoid ammonia.		
Chicago (lake).....	0.00230	0.0678	1,2000	10
Bridgeport.....	17.44900	1.1952	20.5800	10
Lockport.....	10.23000	0.6690	11.3020	10
Joliet.....	6.53300	0.4080	7.7780	9
Ottawa.....	0.38175	0.2375	5.5750	8
Peoria.....	0.03557	0.1877	4.8457	7

Taking the analyses of specimens collected at each place on the same day :

Locality.	Free ammonia.	Loss, per cent.	Albuminoid ammonia.	Loss, per cent.	Oxygen used.	Loss, per cent.	Miles.
Bridgeport ...	26.563		1.6330		26.30		
Lockport.....	12.733	52.1	0.7530	53.9	11.91	58.0	29
Joliet.....	9.426	26.1	0.4320	42.7	7.34	33.4	4
Ottawa.....	0.413	95.6	0.243	43.8	5.30	27.8	48

Total per cent. of loss in passing from Bridgeport to Joliet, 33 miles : Free am., per cent., 64.6 ; alb. am., per cent., 70.33 ; ox. used, per cent., 72.

Our interest is chiefly in the condition of the water, after the pollution by Chicago sewage is supposed to have disappeared ; hence comparing Ottawa and Peoria :

Date.	—Free ammonia—		—Album. ammonia—		—Oxygen used.—	
	Ottawa.	Peoria.	Ottawa.	Peoria.	Ottawa.	Peoria.
1886.						
June 26.....	0.50	0.036	0.23	7.15	7.05	5.04
July 10.....	0.22	0.084	0.164	0.15	4.96	5.04
July 31.....	0.49	0.0048	0.25	0.196	6.00	4.64
Aug. 7.....	0.52	0.0072	0.32	0.21	6.40	6.80
Aug. 14.....	0.30	0.042	0.144	0.19	4.80	4.72
Aug. 28.....	0.36	0.009	0.33	0.206	3.12	2.80
Mean.....	0.398	0.031	0.2396	0.1836	5.388	4.84

The stage of water covered by the observations was unusually low. Dr. Rauch, Sec. Ill. State Board of Health, says : " It is entirely safe to say that there was no Chicago sewage pollution of the Illinois River at these points (Ottawa and Peoria), and similar observations made during the freshet period, February and March, 1886, showed no trace of Chicago sewage."

With this evidence of the disappearance of pollution, there remains only the statement that offensiveness can be noticed at Peoria and at all points above when the river is frozen.

When the river is frozen, the volume is usually small, the current feeble, the ice cover effectually excludes light and air, and the low temperature is unfavorable to decomposition. The conditions approach

that of a closed conduit carrying a constant quantity. For all we know sewage could be conveyed in a closed conduit for indefinite distances without change in its character. But we can safely say that increase of dilution will diminish the nuisance in winter as well as summer. Hence an improved sanitary condition may safely be predicated as the result of the plan, if carried out. In the portion of the river now unaffected by Chicago sewage an improved sanitary condition may be expected to follow the removal of the dams, more decided perhaps than will be realized in the parts where the sewage question is debatable. Replacing the stagnant condition caused by the dams by an active current and greatly increased volume during the hot months must do away with much occasion of malaria. The bottoms are generally low and interspersed with large areas of swamp or shallow lakes. The back water of the dams materially increases the area of shallow flowage, just deep enough to encourage vegetation, and during the hot season to favor the escape of gases generated by decomposing vegetation. Decomposing vegetable matter in disgusting masses now floats in the water, and under the action of winds is driven to the shores, where it gives off odors as offensive as sewage, and probably more unhealthy.

From this brief discussion of the sanitary side of the question, I am led to conclude that there need be no fear of offensive pollution or any danger cognizable by chemistry. If there be an element of risk it comes within the province of biology, and is at present too uncertain to be estimated. This risk will be limited to the use of the river water for domestic supply, and can be avoided by thorough disinfection under public authority of the sewage coming from houses in which infectious diseases occur, a precaution which must be adopted for other reasons everywhere. The general sanitary condition, as measured by decrease of malaria, will surely be improved.

Aside from the betterment in general of the malarial condition, the water supply of the towns along the route will be materially improved by the adoption of the big waterway, instead of the lesser. If Chicago sewage is left out of the question the water of the Illinois is unfit for domestic use, but the towns act as if they had no choice and use it. Some of them would do better by a driven well system, for there is a water-bearing stratum accessible. The towns down to, and including, Peoria should use this ground water in preference to that of the river. I fear this source of supply is not available much below Peoria. Bad as the Illinois water is naturally, the towns will, as they arrive at the period of growth when sewerage becomes necessary, pollute it to a condition as bad as Chicago River even if Chicago sewage be excluded. The natural low stage volume at Joliet is, for months at a time, less than 1,000 cubic feet per minute. Joliet now has about 20,000 inhabitants and expects a rapid future growth. Taking Joliet by itself the flow now would be at the rate of 5,000 feet of water to 100,000 inhabitants. But the Des Plaines is and will be polluted before reaching Joliet by the growing suburban towns in the Des Plaines watershed, hence an intolerable condition may be clearly foreseen. From the list of principal towns in Illinois in 1880, it appears that the Des Plaines, Kankakee, Fox, Vermillion and Illinois rivers above LaSalle have the drain-

age of fifteen towns with an aggregate population of 60,270, to which we must add Lasalle, 8,988; Peru, 5,067; Henry, 1,728; Lacon, 1,814; Chillicothe, 936; Peoria, 29,319; Pekin, 5,988; Havana, 2,118, and Beardstown, 3,136; total, 119,364. At Lasalle the natural low stage flow is not more than 38,000 feet per minute. The urban population, including Peru, was 75,000 in 1880. At Peoria the discharge is but little greater, and the population in 1880 was 108,000, probably over 150,000 now. With these facts in mind, what is the probability of having potable water in the Illinois at any point of its length, when the density of population in the tributary country shall have increased to that of Europe or even New England? So far as St. Louis may be interested in the condition of the water coming into the Mississippi from the Illinois, these facts should receive careful consideration. To the above view of the inevitable condition due to pollution add the stagnancy due to the proposed series of dams, and I think all will agree that the sanitary argument is against the little and decidedly in favor of the big waterway.

ECONOMICAL RESULTS.

A waterway of capacity virtually extending the Mississippi at its best to the lakes must of necessity be of moment in the matter of trade movements. It contains a potency that is capable of changing their direction when supplemented by developments sure to come with time. The result may be considered with reference to the effect upon the trade of a particular locality, or, more broadly, with reference to the trade of the country. To forecast results of this character is scarcely within the province of the engineer, and I shall not undertake more than to point out a few possibilities.

Our present ideas of trade movements are based upon an European market for breadstuffs and provisions, and the Atlantic States as the source whence manufactured products chiefly come. I do not think these conditions permanent. The last few years have seen a woful decline in the price of breadstuffs and the closing of European markets to our provisions, the former at least caused by competition with new sources of supply, which have been opened by extension of railways in India, Russia, and the Northwest. The competition has come to stay, and in the end the direction of our trade will change to new foreign markets with new commodities, and by the development of the home markets. Gas fuel, natural or manufactured, is another element that is likely to change the course of trade, by transferring the seat of manufacturers from the East to the central West, where abundant coal deposits invite the manufacture of fuel gas in localities where the natural cannot be had. The water power created along this canal, about three times that afforded by the Mississippi at Minneapolis, and correspondingly greater than the power at Lowell and Holyoke, will invite a beginning of the change of manufacturing centres. Raw material, as accessible here as elsewhere, cheap food, and the central position with reference to distribution of manufactured products, are potent factors in bringing about a new location of trade centres, whose effect may not be fully realized in a single generation but is sure to come. We, in this matter, are not building for to-day merely.

By natural position, at the point of division, at the water-shed, so to

speak, Chicago will be at the principal focus of the new trade world. St. Louis will be on the main commercial line and in the field of industrial activities, hence she should speed the day of change as the day of her best opportunities.

St. Louis has often been charged with opposing improvements on insufficient grounds, simply because she suspects that they may be injurious to her interests. The charge means no more than that St. Louisans are human. To this instinct her uncompromising hostility to the Hennepin scheme is largely due. Chicago has, under a mistaken idea of her interests, heretofore promoted that project with influence and money. Lately, through the intelligent efforts of her civil engineers, Chicago's influence has been turned in favor of the grand waterway I am discussing. St. Louis engineers have now an opportunity to prove their value in the community, by ascertaining how St. Louis interests will be affected, and bringing this community to an intelligent position toward this subject when it comes up for consideration in Congress, as it probably will next winter. A Senate amendment of the River and Harbor Bill orders a survey of the route and study of the project I have presented in this paper.

Unfortunately a deep-rooted prejudice exists in St. Louis from an unnecessary association of a waterway to the lakes with Hennepin, and more recently on account of Chicago sewage on the part of those who do not know that so far as Chicago sewage can affect us we have had it in full measure for five years.

I have already said that Hennepin, as usually presented, is antagonistic to this large waterway project, but the converse is far from true. The large waterway will readily swallow any contributions to its traffic that may be brought by way of the proposed Hennepin Canal from the upper Mississippi, and will stand ready to forward it north to Chicago or south to St. Louis with entire impartiality. The goods will go to the best market. I, for one, do not believe that the use of the Hennepin Canal, if built, would in tons and bushels either make or mar the fortune of the city to which it may chiefly go. This great waterway is a project of another sort. It seeks not the trade of any section and its benefits must not be sought in the history and movements of the products of any locality, but rather in the grander movements which it will stimulate. The share of different cities in the resulting business will not be equal, but all can have a share and be the richer for that share.

The project before us proposes a depth for navigation of not less than 10 feet, preferably 14, with practically no limit to length or breadth of vessels. Locks, say 450×80 feet. The Canadian canals have locks $270 \times 45 \times 14$ feet. The United States improvements of lake ports and the channels through the Detroit and St. Clair rivers contemplate 20 feet draft. The proposed channel would pass the largest lake vessel light, and most of those now in existence loaded. But I do not anticipate a commercial use of the route by lake vessels. It would open a way by which such vessels could seek employment during winter in trade between the Gulf ports and the West Indies or Central and South America, and so powerfully aid in building up such a trade. The actual traffic through the canal I think would mostly be carried by barges.

In this connection it is proper to consider the suitability of the proposed channel for navigation. The canal is to have capacity to pass 10,000 cubic feet per second at a velocity not greater than two miles per hour, three feet per second. The section must be about 3,300 square feet, and several alternative suggestions have been made. The Chicago Drainage Commission proposed 200 feet surface width by 18 feet in depth. The representatives of the Illinois and Des Plaines valleys demand 160 by 22, and Mr. Cooley has suggested 150 by 24. The first and last represent about the extremes. The amount of excavation above water line is a potent factor in limiting width, by increasing cost. On the other hand, the surface width, for the passage of vessels at speed, cannot be reduced below 150 feet.

Assuming, for illustration, that the depth of excavation above the standard water line will average 10 feet, the three sections named will call for a prism of excavation of 5,600, 5,120, and 5,100 square feet, respectively. The proportion of rock to earth will certainly increase, and with it the cost, as the section is narrowed and depth increased. If the river part of the route is to have a depth of 14 feet, then I do not see any material gain from a depth of canal more than fifty per cent. greater than the maximum draft of vessels. This consideration, together with the increased freedom due to 10 feet more width, inclines me to prefer the section 160×22 feet. With that depth the canal from the lake to Joliet would be accessible to the largest lake craft at all times.

The current of two miles per hour will be somewhat against north-bound traffic, but will be little in excess of the current that must be met by such traffic in ascending the Illinois, and is much less than encountered in the Mississippi, so that looking at the route as a connection between the Gulf of Mexico and the great lakes, the current in the most northern 29 miles is of little real consequence.

The proposed increment of volume in the river below LaSalle will probably add to the natural low water depths about as follows:

Locality.	Natural depth.	Increase.	Channel depth.
LaSalle.....	1.25	10.75	12 feet.
Hennepin.....	1.50	9.50	11 "
Lacon.....	4.00	8.00	12 "
Peoria.....	3.50	8.00	11 "
Beardstown.....	3.00	6.00	9 "
Westport.....	3.00	4.00	7 "
Mouth.....	4.00	2.00	6 "

The deepening of the channel by scour would first be felt in the lower part of the river, where the quickening of the current would be the most marked, also because the shoals in the lower part of the river are of material more readily acted upon than those above. A deepening to afford 10 feet draft at the lowest stages may confidently be expected throughout the Illinois, as the result of natural forces supplemented by a reasonable amount of dredging and concentrating works. The increment of volume will also materially benefit the Mississippi. Ordinary low water volume in the Mississippi at Grafton may be taken at 30,000 cubic feet per second. By the discharge curve, derived from the observation of 1881, $Q = 449G^2 - 4404G + 8062$. The discharge of 30,000 cubic feet corresponds to a height on gauge of 13.4, at which stage the differential for one foot change of stage is 7,530 cubic feet per second; hence

the increment will be enough to raise the stage one and one-third foot, adding that much to the channel depth in the Mississippi apparently. Boatmen tell us that their experience is that one foot rise out of the Illinois gives double increase in channel depth below the Illinois, whereas a foot rise on the gauge at low stage, the water coming from the Missouri, will rather diminish than increase channel depth. This difference is attributed with reason to the fact that the Illinois furnishes clear water, the Missouri silt laden. The proposed increment being clear water after the process of channel enlargement is complete, we have reason to expect an increased depth in the channel from the Illinois to the Ohio at least equal to the computed increase of height on gauge at Grafton. My firm belief is that the increase of the low stage volume below the Missouri by the one-sixth part will benefit the channel much more by scour than by direct raising of the surface.

Tracing the possible effect, I obtain from discharge curves the following :

Locality.	Low stage volume.	Volume to raise one foot.
St. Louis.....	60,000	10,500
Columbus.....	130,000	16,400
Fulton.....	131,000	19,550
Memphis.....	132,000	21,400

From these figures one is justified in saying that the beneficial effect of the increment can be traced as far as Memphis. In fact the volume required to raise the river one foot is greater at Memphis than at any lower point until we approach Carrollton, where a foot rise requires nearly 44,000 cubic feet increase of volume.

The increase of volume will have an important economical effect by creating water power along the part of the route lying between Lockport and Ottawa. The fall is 145 feet, the volume will be reliably constant and the horse-power available will be, between Lockport and Lake Joliet, about 50,000, and between Lake Joliet and Ottawa about 40,000. The natural water privileges along this part of the route have fostered several thriving manufacturing towns; we may therefore expect that the more valuable power created by the canal will be utilized. The industries so brought into existence will add to the trade along the route and to the general prosperity of the country.

POLITICAL EFFECT.

All now admit that transportation routes bind the country together more firmly than any other agency by fostering community of interests. As a matter of internal politics it will be well to complete this north and south bond. So long as we have a neighbor to the north whose interests are not identical with ours, there is a possibility of breach of friendly relations, and as a matter of prudent outside politics, it would be well to have a way open by which a defense for our lake cities can be provided without breach of existing treaty obligations. With the Illinois waterway improved upon the scale proposed, we will always have it in our power to meet our neighbor on the lakes upon terms of equality. If any lesser scale is adopted, we deprive ourselves of the only opportunity to secure equality short of maintaining a lake fleet and costly fortifications.

One word in closing as to the division of the burden of construction.

The United States might with propriety do it all, but if any municipality can see a benefit from anticipating the action of the general government, and in doing a specific part of the whole work, there can be no reasonable objection to its doing so. Chicago, in view of the delays attending the execution of public works by the United States, will be compelled to excavate the channel from the lake to Lockport. And it is by no means certain that associated capital may not solicit the privilege of doing that part of the work, looking to enhanced values of land along the line and control of dock privileges for compensation. In addition to these possibilities, the State of Illinois might find in the construction of the canal the solution of the trying political question, what to do with the labor of convicts in the penitentiary at Joliet. If any of these plans be followed, the United States will only have to prepare the Des Plaines and Illinois to receive the increased flow and to provide the locks needed between Lockport and LaSalle.

FAILURE OF A FIRMENICH BOILER.

BY CHAS. F. WHITE, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 16, 1888.]

On the morning of October 3, 1887, a boiler at Plant's flour mill in this city exploded with great violence and fatal results. This explosion excited considerable interest among engineers and steam users, from the fact that the boiler was a form of the water-tube type but recently brought into use in St. Louis. As a water-tube boiler it was put upon the market as one free from the danger of disastrous explosion. As it is a generally accepted opinion that water-tube boilers are more safe than those of the fire-tube type, I have endeavored to find, if possible, the immediate or remote causes of this occurrence, and to point out the sources of danger in similar boilers in use about the city.

Many of you may recall the accounts given at the time of this explosion, and some examined the premises after the accident. For others I will briefly describe the situation and the physical aspect of it. The mill itself is a brick structure about 75 feet high, occupying the northwest corner of Main street and Chouteau avenue; between the west end of the mill and Risley street, occupying the northeast corner of that street and Chouteau avenue, was a one-story building used for engine and boiler rooms. The floor of this part of the building was about 8 feet below the street level ground. The engine room was next to the mill, and the Firmenich boiler was placed close up to the west wall. A Babcock and Wilcox boiler occupy the space between the engine-room wall and the Firmenich. Steam from each boiler was carried to a large receiving drum suspended in the engine room, and from this was carried to the engine.

The details of the boiler room, viz., safety valves, feed pumps, feed water heater, gauge cocks, glass water gauges, etc., were well provided and suitable for the duty required of them.

Both boilers were under steam and in service.

The Firmenich boiler in this case consisted of a pair of horizontal drums at the bottom, about 6 feet apart; also a pair of similar drums, some 2 feet apart, parallel to the first pair, but at a height above them of about 15 feet. The upper and lower drums were connected by 126 tubes, 3 inches in diameter and 16 feet long. The upper drums being nearer together than the lower ones, the tubes were not upright, but inclined like the legs of the letter A. These water tubes were placed in four rows on either side. The four similar drums were $16\frac{1}{2}$ feet long each by $7\frac{1}{2}$ feet perimeter, and in section were about three-fifths of a circle, the chord forming a flat surface for the reception of the water tubes, which were expanded into the tube sheet so formed. A large water-leg near the rear connected the lower drums, while above the upper pair was a steam drum having two connecting legs on either side opening into the upper water drums. The water level in this style of boiler is about halfway the height of the upper drum, and the feed water was introduced into the boiler just below the water line in these drums.

The furnace was in the space between the water tubes extending from side to side, and back about half the length of the boiler, more or less according to the amount of grate surface needed. About two feet from the rear of the boiler a brick curtain formed the bridge-wall rising nearly to the upper drums. The whole structure was surrounded and covered with brick walls forming the furnace walls and ends.

An examination of the wreck immediately after the explosion seemed to show that the boiler gave way along the edge of the tube sheet on the upper drum on the east side. This is evidenced by the fact that the four legs connecting the steam drum with the water drums had crushed in the shells of the drums, although all of them were found torn from their fastenings.

The steam drum was not much damaged itself, but was thrown with such force as to land much like a rocket stick on the roof of a two-story dwelling house some 200 feet distant, through which it plunged into the cellar. This house stands on the west side of Risley street, the direction from the boiler house being west of north. The west upper water drum was thrown in a direction almost due west, passing diagonally through the roof of a two-story stable, and lodging part way through the west wall of the building. This drum was torn apart at the middle circumferential seam, but not much ruptured otherwise. The upper drum on the east side of the boiler was thrown in a direction a little north of east, or nearly opposite to that of the other drum. It must have risen in a path nearly vertical, since it was found nearer where it started from than the others were; yet it must have passed clear over the top of the mill to reach the place where it fell on the railroad track north of the mill building. This drum was not torn in two entirely, but was ruptured and much spread out along one edge of the tube sheet. No one could view the condition of this part of the wreck and fail to get a very vivid impression of the force that had been acting upon it, so much was the iron shattered and torn. The tubes of the boiler were for the most part left standing in their places in the lower drums. Some were thrown about and some were bent, probably by the

wreck of the building. The houses on the west side of Risley street, opposite the boiler house, were about half blown down.

The walls of the boiler house were thrown out in each direction. The roof was partly thrown over against the mill building, a circumstance that saved the life of the engineer. The mill building itself was almost uninjured, the force of the explosion finding vent chiefly to the west. The structure of the Babcock & Wilcox boiler acted to some degree as an anvil to take up the force on the east side. That boiler was somewhat crushed and broken, but did not in any sense explode. The lower drums of the exploded boiler did not move much from their positions.

Here, then, we have a boiler of the water-tube type, with no very large body of water or steam in one shell, which, instead of failing in some minor part, as it is supposed such boilers should, without damage to the whole, has shown itself fully equal in destructiveness to the Mississippi steamboat boiler in its palmy days. I believe this is not the first case of the explosion of a Firmenich boiler. The facts show plainly enough that even the comparatively small drums used are large enough to hold plenty of destructive energy if it is permitted to escape control. It is of value to know if this particular form of boiler has elements of weakness peculiar to itself, and how far will causes at work in this case affect other forms of water-tube boilers.

Naturally enough a first thought is that some neglect of duty by those in charge of the boiler was the direct cause of the disaster. The fireman on watch that morning was killed, but the mill engineer was on duty, and was in the boiler room but a short time previous to the explosion. This engineer, the night fireman and two others recently employed there were examined under oath by the City Board of Engineers. A carefully prepared series of questions, covering the occurrences of that morning and also the usual practice in care of the boilers, was answered categorically, beside other questions. The testimony of these men was, I think, plain and consistent. I have not been able to find any reliable evidence that any proper precaution was neglected or that the boiler was injured through lack of care. The only man who could give the whole story was the engineer, since the fireman lost his life. The account given is substantially this. The day previous the boilers had been shut down to allow replacing a leaking tube in the Babcock and Wilcox boiler. The boilers were filled with water the night before, the Firmenich being filled somewhat too full. At 5 o'clock Monday morning the fires were lighted. At 5:45 the water in the Firmenich boiler was drawn down to a point a little below the top of the glass gauge. At 6:10, there being some steam pressure the engineer went to the top of the Firmenich boiler to examine and tighten the gaskets in the manholes. While there he tried the gauge cocks, finding water at the proper level. An hour later, at 7:10 A. M., the mill engine was started. After running some ten minutes the miller rang to stop the engine for some cause in the mill. It was ten minutes before the signal to start again came. Having started the second time the engineer went into the boiler room and looked at the condition of the fires, and directed the fireman to put coal on each fire. He also looked at the water in each glass gauge, each one showing water at the ordinary height. The steam gauge registered

ninety-five pounds. The safety valves were set to blow at one hundred pounds pressure. The one on the Babcock and Wilcox boiler, however, opened slightly sooner than the others, and had previously been threatening to blow, although no discharge had occurred that morning. The engineer went back to the engine-room, passing behind the cylinder of the engine, reaching that position about five minutes after starting the second time. The explosion came just at that moment.

The boiler was built of lap welded tubes and iron plates. The plates were three-eighths of an inch thick and were stamped Central Iron Works, Harrisburgh, Pa., C. H. No. 1, 45,000 pounds tensile strength. Seven test specimens were cut from the tube sheet of the east drum. Five of these specimens were cut lengthwise the sheet, two across the grain. These were broken in the Testing Department at Washington University with these results :

	1.	2.	3.	4.	5.	6.	7.
Breaking strength...	52,800	58,900	55,400	51,700	50,100	55,700	56,800
Elastic limit.....	26,700	34,000	31,700	29,600	34,700	41,300	40,000
Elongation, per cent. ....	.....	.....	.....	12½.	6	8	.....
Reduction of area, per cent.....	4	2½	28	37	31	28	23

Average tensile strength with the grain, 539,940 pounds.

Average elastic limit, 35,400 pounds.

Per cent. of elongation in 6 inches, 8.83.

Per cent. of reduction of area, 29.4.

These tests do not give as uniform results as might be desired, but the plate from which the tests pieces come had been subjected to some treatment, and taken together they do not give us ground to believe that the iron was inferior in quality for the work expected of it, the strain due to 100 pounds pressure in a 30-inch drum of three-eighth inch plate being 4,000 per square inch of section.

It is not easy to judge of the workmanship put into the construction of a boiler examined after such a wreck. I have not found any strong evidence of defective workmanship in this one. I have endeavored to learn what the regular duty required of the boiler outfit was, and while exact figures are not to be obtained, I think I can make a fairly reliable estimate. The Babcock & Wilcox boiler had 2,600 square feet of heating surface and was rated at 250 horse-power.

The Firmenich boiler had 3,375 square feet of heating surface, and was rated at 225 horse-power.

I was not able to secure indicator diagrams taken during the time that the boiler in question was in use, but was told that there was seldom more than 500 horse-power used.

The mill water-meter for six months previous to the explosion showed a consumption of about 8,000 pounds of water per hour. Nearly all of this goes to the boilers, and they also use some condensed water, but I cannot from this source find warrant for assuming that 500 horse-power was regularly required of these boilers.

Probably on the average the evaporation per square foot of heating surface from these boilers was about 2 pounds an hour, a rate which cannot be regarded as excessive. But there may have been times when they were overcrowded, and also we cannot tell just what proportion of

the whole each boiler performed. The opinion of the engineer was that the Babcock & Wilcox boiler did the larger share of the duty.

We are now brought to a consideration of the design and construction of the boiler and its operation in practice.

It will be noticed that the drums at top and bottom are not of a circular section, but are flat on one side; in the case of this boiler, the flat part being nearly the diameter of the drum. Two such drums are connected by straight water tubes in four parallel rows. The whole of this structure is subjected to internal pressure. This pressure, acting on the area of the open tubes, tends to force the drums apart, making a tensile strain on the expanded joints. The internal pressure also makes an effort to bring the drum into a circular cross section. The resisting force opposed to this is also the expanded tube joints. It will also be seen that the real net effect of the internal pressure is to cause a pull upon the outer row of tubes considerably greater than would be the case with the fire tubes of a shell boiler spaced in the same way. The more so since the pressure tending to bulge the flat tube sheet acts through a longer lever arm than does the resisting tube.

But a more serious cause of severe strains in this structure is that of the unequal heating of the water tubes in various parts of the boiler, these water tubes being so fixed at the ends as not to be free to move.

I think it plain that two causes contribute to this result.

The first is that the fire in such a boiler is near one end, exposing the nearest tubes to a very intense and direct heat. Where four rows are used, as in this boiler, two of the rows are well shielded from radiant heat, and are also well out of direct currents of hot gases.

In the boiler in question, all tubes that have failed and required replacing were a little back from the front end and in the row next the fire. Internal incrustation is another cause of overheating, which, in this boiler, means undue expansion, and hence severe strains.

All persons examined agreed in the statement that heavy firing or unusual heat, such as is caused by breaking down a fire, always caused a strong pulsation of the water level in the glass gauge; the water sometimes disappearing and then raising 12 to 15 inches with a regular wave motion. I have elsewhere noted a jet-like pulsation in the flow of mingled steam and water from a heated tube. Should such motion ever leave a tube partially free of water, as can readily be imagined in a tube of a length of more than 50 diameters exposed to high heat, the scale would be at once hardened on the internal surface. That the scale does so harden to such a degree as to very nearly fill the tubes in Firmenich boilers, is a well-known fact to users of that boiler in St. Louis.

Here then are to be found the causes of the disastrous failure of this boiler, and these elements of weakness are at work with more or less effect in all such boilers now operated here. Moderate working and careful watching at all points may prevent the repetition of such an explosion, but I think it is beyond question that the design is a faulty one and unsafe to be put upon the market.

It is to be noted that when any form of water tube boiler is used where the water contains scale-producing elements, this scale is very liable to be deposited on the walls of the tubes, and it is not easy to remove it

when once hardened. A fire tube receives its deposit of scale on the outside while hot and expanded. Cooling down as during cleaning tends to loosen such scale. With a water tube the reverse is true. The scale is deposited on the inside while the tube is expanded, and upon cooling the incrustation is firmly held by the contracted tube. Cases have occurred in St. Louis, I believe, where it was easier to replace the tubes than to get the scale out of the inside, where it was held almost like solid stone. Under such conditions it becomes very important that the distribution of heat be uniform in amount on the tubes, especially on those in proximity to each other, or that the tubes be free to expand without setting up strains in the structure of the boiler. I have thought it worth while to compare the boiler under discussion with one or two other forms of the water tube type in the points specially noteworthy. These are distribution of heat and freedom of expansion. Reference has been made to the Babcock & Wilcox boiler, of which quite a number are in use in the city, and which is typical of several other makes. With this boiler the tubes are in sets, each set extending from the top to the bottom of the tube system, the tube of each set being connected by a steel casting. Each set then is free to expand independent of those alongside. In this style of boiler the heat of the fire is nearly equal across the entire width of the boiler, and the hot gases crossing the length of the tubes three times bring a reasonably uniform degree of heat to bear on every tube.

Another typical boiler is the Heine. The tubes of this boiler all terminate in flat tube sheets, but these tube sheets are in such shape as to permit of proper staying. The water legs of this boiler are perhaps to some degree free to spread apart at the lower ends, but cases are not wanting where the tubes have been very much buckled by undue expansion. The course of the hot gases in this boiler is such as to heat the lower tubes much more than the upper ones, although, as with the Babcock & Wilcox type, the heat received by the tubes in each horizontal series is nearly equal. The greatest expansion is thus produced in those tubes that are least resisted by the plates of the tube sheets.

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

- Aqueduct, Zempoala, Mexico.** Gives an illustrated description of Zempoala aqueduct, supplying the city of Otumba, which was built during 1553-7. *Engr. News*, July 7, 1888.
- Asbestos.** By S. A. Rogers, before the Chemists' Assistants' Association. Reviews the history, occurrence and properties of asbestos. *Sci. Am. Suppl.*, June 16, 1888.
- Bridge, Arthur Kill.** Gives a brief description, with plan and details of the draw-bridge recently constructed between Staten Island and New Jersey. Total length of draw, 496½ feet; clear water-way, 203 + 204 feet. *R. R. Gazette*, June 22, 1888.
- , *Big Warrior River.* Gives a brief description of a 300-ft. through span over the Big Warrior River, near Cordova, Ala., with full detailed drawings. *R. R. Gazette*, June 29, 1888.
- , *Niagara, Replacing Towers of.* By L. L. Buck before the American Society of Civil Engineers. Gives details of the work of replacing the stone towers of the Niagara suspension bridge with iron towers. *Trans. Am. Soc. C. E.*, Vol. XVII. (Oct. 1887); pp. 204-212, *Engineer*, Dec. 9, 1887.
- , *Tay.* By Peter Barlow before the Institution of Civil Engineers. Gives principal dimensions and general data of the Tay viaduct. *Sci. Am. Suppl.*, June 16, 1888.
- , —. By Wm. Ingliss before the Institution of Civil Engineers. Gives details of the construction and difficulties overcome of the Tay viaduct. *Sci. Am. Suppl.*, June 16, 1888; *R. R. Gazette*, June 29, 1888.
- Bridges, Highway.** By S. A. Buchanan. Discusses the construction, maintenance and repairs of short span highway bridges. *Rpt. Ohio Soc. Surv. and Eng.*, 1888, pp. 184-194.
- , *Highway, Computation of Strains in.* By C. M. Brewn. A paper showing county commissioners and surveyors how to compute strains in highway bridge structures. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 195-203.
- , *Inspection and Maintenance of.* A discussion at the annual convention of the American Society of Civil Engineers on the inspection and maintenance of railway structures. The discussion, by many prominent engineers, covers 59 pages in the *Trans. Am. Soc. C. E.*, Vol. XVII., December, 1887.
- , *Water-Way for.* By A. M. Talbot. Discusses the determination of water-way for bridges and culverts, proposes a new formula. *Selected Papers C. E. Club. Univ. of Ill.*, 1887-8, pp. 14-22.
- Bridge Work and Inspectors.** By S. T. Wagner. Before the Annual Convention of the American Society of Civil Engineers. Discusses the characteristics and work of bridge inspectors and make suggestions for their work. Discussion. *Trans. Am. Soc. C. E.*, Vol. XVII., December, 1887, pp. 319-329.
- Cable Roads, Birmingham, Eng.** Gives a brief description, with a two-page detailed drawing of the Birmingham cable road. *Engineer*, June 22, 1888.
- Canal, Manchester Ship.** A series of articles describing in detail the progress made and methods employed in the construction of the Manchester ship canal. *Engineering*, May 18, *et seq.*, 1888. Abstracted *Engin. News.*, June 30, *et seq.*, 1888.
- , *Nicaragua, Location of 1888.* Gives maps showing results of the survey of the Nicaragua canal during 1888, with full description of the work to be done. *Engin. News*, July 14, 1888.

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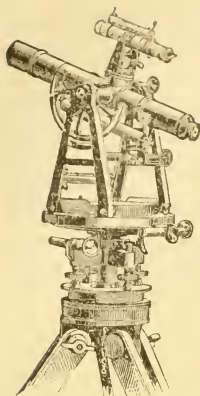
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- Canal, Panama and its Rivals.** By J. S. Jeans before the Society of Arts. Gives a brief review of the historical, engineering and commercial aspects of the Panama and Nicaragua canals. *Jour. Soc. Arts*, April 6, 1888.
- Car Heating, Continuous Steam.** Gives tabulated results of experiments in continuous heating, from reports collected by the Committee of the Master Car-Builders' Association. *R. R. Gazette*, June 22, 1888; *Engin. News*, June 30, 1888.
- Cement and Mortar, Selection, Inspection and Use of.** By S. F. Burnet before the Engineers' Club of St. Louis. Gives practical hints in regard to the selection, inspection and action of cement and sand, and the methods of mixing and using to produce a good mortar. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 258-264.
- , *Compressive Strength of.* Progress Report of the American Society of Civil Engineers' Committee on the compressive strength of cements and the compression of mortars and settlement of masonry, with five plates. *Trans. Am. Soc. C. E.*, Vol. XVII. (Nov., 1887), pp. 218-218.
- , *from Waste Product Lime.* By J. S. Rigby, before the Society of Chemical Industry, Liverpool University. A valuable paper on the utilization of waste lime from chemical process for the manufacture of cement. *Sci. Am. Supple.*, June 16, 1888.
- , *Testing Portland.* By H. Farja, before the American Society of Civil Engineers. Gives details of the method employed by himself for a number of years; shows details of apparatus for mixing and testing cements. *Trans. Am. Soc. C. E.*, Vol. XVII. (November, 1887), pp. 218-228.
- Disinfection.** Describes the machines used for disinfecting clothing, bedding, etc., by means of hot air and steam, acting separately and in combination. *Engineer*, May 11 et seq., 1888; *Sci. Am. Supple.*, June 30, 1888.
- Docks, Pontoons and Floating.** By Alex. Taylor, before the northeast coast Institution of Engineers and Shipbuilders. Gives approved practice for pontoons and floating docks. *Sci. Am. Supple.*, July 7, 1888.
- Drainage, Land.** A paper by E. B. Opdyck, on the construction, comparative cost and efficiency of tile drains and open ditches. *Rpt. Ohio Soc. Surv. and Engs.*, 1888, pp. 148-155.
- Drawings, Duplication of.** By J. M. Bradford. Describes the "blue prints" method, with formula. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 256-261.
- Dynamo, Mordey's Alternating Current.** Gives an illustrated description of Mordey's new alternating current dynamo. It has fixed armatures and revolving magnets. *Tel. Jour. and Elec. Rev.*, June 1, 1888.
- Electric Lighting, Efficiency of Incandescent Lamps.** By W. E. Ayrton and J. Perry before the Physical Society of London. Treats of the efficiency of incandescent lamps with direct and alternating currents. The mean of 75 experiments gave some results for both. *Tel. Jour. & Elec. Rev.*, June 1, 1888.
- Electric Motor, How to make a Simple.** By G. M. Hopkins. Gives full instructions by which a motor can be made with ordinary tools. Illustrated. *Sci. Am. Supple.*, April 14, 1888; *Tel. Jour. & Elec. Rev.*, April 13, 1888.
- Electricity, Influence Machines.** By James Wimshurst before the London Royal Institution, giving a full account of the recent forms of generators of static electricity. Illustrated. *Tel. Jour. & Elec. Rev.*, May 26, 1888.
- , *Kirchoff's Laws and their application.* By E. C. Rimington. Gives a good description of the application of Kirchoff's laws to the finding of currents in a network of conductors. Illustrated with many diagrams. *Tel. Jour. & Elec. Rev.*, March 2, et seq., 1888.
- , *On Flashing Carbon Filaments at Different Temperatures.* By L. S. Powell. Gives details and results of experiments made to obtain a clearer insight of what really goes on by employing different temperatures in flashing. *Tel. Jour. and Elec. Rev.*, May 4, et seq., 1888.
- Engine, Gas, Beck's.** A report of an exhaustive series of experiments made by Prof. A. B. W. Kennedy on Beck's gas engine. Illustrated. *Engineer*, May 4, 1888. Abstracted *Engin. News*, June 9, 1888.

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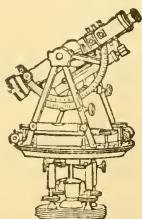
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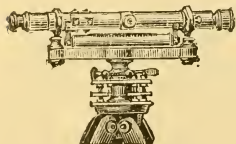


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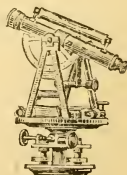
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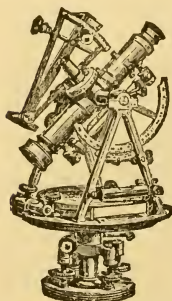
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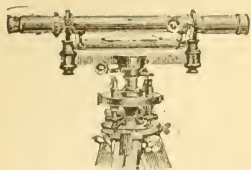
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- Engine, Gas, Sturgeon.** Brief description, with drawing of the cylinders of the Sturgeon gas engine. *Engineer*, June 15, 1888.
- , *Petroleum Spirit.* Gives a series of interesting diagrams from a petroleum spirit engine. *Engineer*, June 15, 1888.
- Explosives and their Composition.** By W. C. Foster. Gives a list of the explosives most commonly used, with the composition, and references to publications in which notes may be found. *Engin. News*, June 30, et seq., 1888.
- Falls of St. Anthony, Preservation of the Apron at the.** By A. Johnson, before the Engineers' Society of St. Paul. Gives description of the Falls of St. Anthony, the main work constructed for their preservation, and describes in detail the construction of a crib to protect the apron of the falls. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 271-279.
- Friction of Collar Bearing.** Gives the third report of the research committee "On Friction" of the Institution of Mechanical Engineers. Report gives results of experiments on the friction of collar bearings, with description of apparatus. *Engineer*, May 4, 1888.
- Foundations, Pile.** By Julian Griggs. Describes the common methods of managing pile foundations for bridge masonry and trestles. *Report Ohio Soc. Surv. and Engrs.*, 1888, pp. 209-216.
- Fuel, and Combustion.** By R. H. Buel. Gives a general synopsis of the most important principles and data from various sources. *R. R. Gazette*, July 13, 1888.
- Gas.** See Water Gas.
- , *Fuel.* By Walton Clark before the Western Gas Association. Compares the relative efficiencies of pure fuel gas and a mixture of coal, water and producer gas. *Am. Manuf. and Iron World*, June 22, 1888.
- Hydraulic Lift, Neuffossé Canal.** Brief description, with sections and elevation of the hydraulic lift at Fontinettes, on the Neuffossé Canal. *Engrs. and Build. Rec.*, June 23, 1888.
- Hydraulic Power, Distribution of.** By E. B. Ellington, before the Institution of Civil Engineers. Gives details of the distribution of hydraulic power in London. Has 27 miles of mains at a pressure of 700 lbs. per sq. in. *Engineering*, April 27, 1888; *Engineer*, May 11, 1888; *Mech. World*, May 12, 1888; *Amer. Eng.*, June 27, 1888.
- Irrigation, Evils of Canal, in India.** By T. H. Thornton, before the Society of Arts. Discusses the evils arising from canal irrigation in India, viz.: impoverishment of soil, waterlogging and poisoning, and malarial influences, and suggests remedies for them. *Jour. Soc. Arts*, March 23, 1888.
- , *Injurious Effects on Health in India.* By Surg. Gen. H. W. Bellew, before the Society of Arts. Gives results of personal observation of the injurious effects of canal irrigation on the health of the population of the Punjab, and their remedy. *Jour. Soc. Arts*, May 11, 1888.
- Iron, Mechanical Properties of Pure, as a standard base.** By President Adamson, before the Iron and Steel Institute. *Amer. Eng.*, July 6, 1888.
- Locomotives. Extension Fronts and Fire-Box Arches.** Gives the report of the committee of the Master Car-Builders' Association on extension fronts and fire-box arches. *R. R. Gazette*, June 22, 1888; *Nat. Car and Locomotive Builder*, July, 1888; *Master Mechanic*, July, 1888.
- Lubricants, Mechanical Significance of Viscosity Determinations of.** By J. E. Denton before the Nashville meeting of the American Society of Mechanical Engineers. *Amer. Engr.*, June 13, 1888.
- Mechanical Engineering, Chalk Age of.** By J. T. Halloway. Fifth lecture before the students at Cornell University. Gives picture of engineering practices of days gone by and the contrast between the former and modern practice. *Sci. Am. Supple.*, June 16, 1888.
- Mortar Making and Using.** By B. F. Bowen. Contains much useful information relative to lime mortar. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 223-31.
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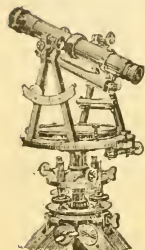
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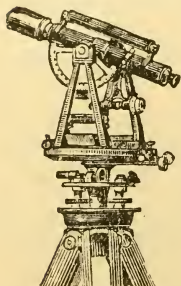
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- Pavements, Wood, in Paris.** Gives a translation of the specifications and principal instructions issued in 1886. *Eng. and Build. Rec.*, June 9, 1888.
- Paving, Notes on.** By T. R. Wickenden. Object of paper is to call attention to desirable as well as objectionable qualities of various pavements in general use. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 69-75.
- Pier, St. Leonards-on-Sea.** Gives brief description, with drawing of details of a screw pile promenade pier 900 ft. long and 25 ft. wide, being built at St. Leonards-on-Sea, England. *Engineer*, May 11, 1888; *Sci. Am. Suppl.*, June 23, 1888.
- Power. Distribution of Hydraulic, in London.** By Baggs and Ellington before the Institution of Civil Engineers. Gives a description of plant of Hydraulic Power Company of London. *Engineer*, May 11, 1888; *Engineering*, April 27, 1888; *Am. Engr.*, June 27, 1888; *Mech. World*, May 12, 1888.
- Public Works. Cullom-Breckenridge Bill.** Arguments on the Cullom-Breckenridge Bill by a Committee of the St. Louis Engineers' Club. A pamphlet of 19 pages. Copies may be had by addressing Prof. J. B. Johnson, St. Louis, Mo.
- Railroad, Canadian Pacific.** The annual address of the President of the American Society of Civil Engineers, Mr. T. C. Keefer, read at the annual convention of 1888. Gives details of construction of the Canadian Pacific Railroad. Abstracted in *R. R. Gazette*, July 6, 1888.
- , **Steel Ties.** By J. W. Post. Before the annual convention of the American Society of Civil Engineers. Gives cost of maintaining track on steel ties on the Netherland State railroads. *Engin. News*, June 30, 1888.
- , **Location.** By Samuel McElroy. Discusses railroad location as one of the most vital questions in railroad construction. *Railroad Gazette*, July 6, 1888.
- Reservoir, Nashville, Tenn.** By H. De B. Parsons. Gives a brief description, with plan and sections of wall of the new storage reservoir being constructed at Nashville, Tenn. *Engin. News*, June 16, 1888.
- , **Remarkable Breaks in a.** By L. N. Lukens before the Philadelphia Engineers' Club. Gives details of a number of breaks and their repairs in Conshohocken Hill Reservoir. *Proc. Engrs. Club, Philadelphia*, Vol. VI., pp. 147-150 (Dec., 1887).
- Rivers and Harbors, Improvements of.** See Public Works.
- Road Material of Ohio.** By Ed. Orton. Describes the stone in Ohio available for road-making material. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 60-68.
- Sewage, Chemical Treatment of Mystic.** By W. T. Learned. Before the Boston Society of Civil Engineers. Gives results of a study of the chemical treatment of Mystic sewage. Percipitant used was crude sulphate of alumina. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 244-248.
- , **Disposal.** By C. A. Allen, before the annual convention of the American Society of Civil Engineers. Gives a brief review of the history of sewage purification in England, and a review of the different methods employed at present. *Trans. Am. Soc. C. E.*, Vol. XVIII., Jan., 1888, pp. 9-23, and a discussion, pp. 24-42.
- , **Disposal, at Medfield, Mass.** By Fred Brooks, before the Boston Society of Civil Engineers. Describes the intermittent, downward filtration sewerage system at Medfield, Mass., with map and plans of basins, etc. *19th An. Rep. Mass. Board of Health. Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 235-244; *Engin. and Build. Rec.*, July 16, 1888.
- , **Disposal, European Practice.** By C. H. Swan, before the Boston Society of Civil Engineers. Gives interesting statistics relative to the amount of sewage that may be applied to given areas of land, as shown by experiments at Paris, Berlin, Croydon, etc. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 248-258.
- , **Disposal in Massachusetts.** By T. P. Stearns, before the annual convention of the American Society of Civil Engineers. Gives a statement of the present status of the question in Massachusetts, with a brief reference to the action of the State in the past. *Trans. Am. Soc. C. E.*, Vol. XVIII., Jan., 1888, pp. 1-7.
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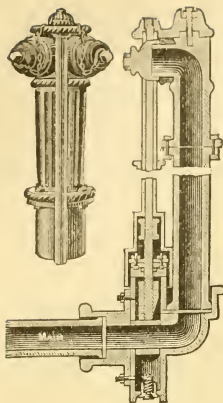
- Steam Engineering.** *River Practice in the West.* By J. M. Sweeney, before the Nashville meeting of the American Society of Mechanical Engineers. *Am Engineer*, June 13, 1888.
- Strength of Materials.** *Z-Iron Columns.* By C. F. Strobel before the American Society of Civil Engineers. Gives details of the tests of 15 columns of Z-iron. Abstracted *R. R. Gazette*, July 13, 1888.
- Survey, Outfit for Railroad.** By Benj. Thompson. Gives description of the outfit of a railroad surveying party and tells how the work was done. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 237-244.
- Telescopes, for Stellar Photography.** By A. Grubb, before the Society of Arts. Describes the telescopes to be used in the proposed international survey of the heavens. *Jour. Soc. Arts.*, April 20, 1888.
- Water Aeration and Filtration.** Paper by Chas. B. Brush, with discussion. Many new and pertinent facts presented, especially in the discussion by Dr. Leeds. *Jour. New Eng. W. Works Assoc.*, Sept., 1887.
- Water Gas, as applied to Metallurgical Processes.** By A. Wilson, before the Iron and Steel Institute. Describes the modifications of Lowe and Strogg's process developed at Essen, and its application to heating purposes and steel melting at Wilkowitz, Terni, etc. *Am. Manuf.*, June 8, 1888.
- Water Hammer, a Discussion,** giving the experience of water-works superintendents. *Jour. New Eng. W. Works Assoc.*, Sep., 1886.
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- Water Supply. Head Required to Produce Velocities in Pipes.** By Chas. B. Brush. Before the Annual Convention of the American Society of Civil Engineers for 1888. Give results obtained in forcing water through a 20-inch main 75,000 feet long. Abstracted *Engin. News*, July 7, 1888.
- . *English Towns.* Discusses the bearing of limited water-sheds upon the future supply of English towns, and suggests the prevention of waste of water. Gives experience in the use of waste meters and house-to-house inspection. *Engineer*, June 15, et seq., 1888.
- Water, Pollution of Air and.** By A. E. Fletcher before the Society of Arts on the present state of the law concerning the pollution of air and water. Shows what the law has done, and what is still hoped for from its further action. *Jour. Soc. Arts*, April 13, 1888.
- Water-Works, Circleville, Ohio.** A brief description of the Circleville, Ohio water-works. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 181-183.
- . *Mercer, Pa.* Gives brief description of the water-works at Mercer, Pa., with plans of engine house, well and filter. *Engin. and Build. Rec.*, June 9, 1888.
- . *Some Practical Details of the Management of.* A valuable paper by Edwin Darling before the M. E. W. W. Association, with discussion. *Jour. New Eng. W. W. Association*, September, 1887.
- Water Tanks of Iron.** A paper by P. Kieran, and discussion on same. Describes 1,160,000 gallon tank at Fall River, Mass. *Jour. New Eng. W. Works Assoc.*, September, 1887.
- Water Waste.** A paper by Dexter Brackett. Causes methods of prevention and results accomplished. *Jour. New Eng. W. Works Assn.*, Dec., 1886.
- Weights and Measures.** *Report of the Committee of the Boston Society on.* Comprising a canvass of the society regarding metric reform, with opinions of members and a notice of the recent act of Congress. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 264-271.

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CABLE RAILWAYS.

BY JOHN WALKER, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read July 10, 1888.]

Since Mr. A. S. Hallidie put his first street cable railway in operation on Clay Street Hill road in the City of San Francisco, California, in August, 1873, this very interesting subject has had considerable attention, but not until late years has it had the attention it deserves. For nine years the benefits of this system were confined to San Francisco; since 1882 (in less than six years) Chicago, Ill., New York, N. Y., Kansas City, Mo., St. Louis, Mo., Cincinnati, O., Philadelphia, Pa., Los Angeles, Cal., Oakland, Cal., Omaha, Neb., Binghamton, N. Y., Grand Rapids, Mich., Hoboken, N. J., Peoria, Ill., St. Paul, Minn., London, Eng., Birmingham, Eng., Melbourne and Sydney, Australia, and also New Zealand, have availed themselves of this ideal method of transit, and many more cities are now obtaining franchises and contracting for road material and machinery.

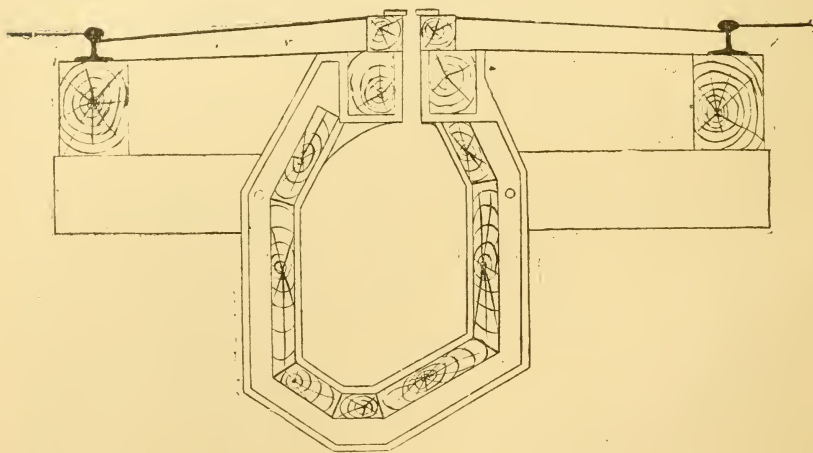
It is not necessary for me at this time to enter into the history of cable railways, the subject being of so recent origin and well ventilated in our public journals; something, however, may be said of the construction, operation and maintenance of these roads, to which points I will confine myself this evening.

Under construction we may speak of roadbeds, driving machinery, grips, cable and cars. The introduction of cable railways meant an introduction of another branch of engineering, in which both civil and mechanical talent were necessary; the problems and difficulties have been met from time to time, and solved generally in a very satisfactory manner. The roadbed is usually built with yokes 4 feet 0 inch centres, to which is attached the track rails at the outer ends, and the slot rails at the centre. These yokes have been made of different designs, all with a view to strength and rigidity to maintain the roadbed in proper align-

ment, and prevent the slot from closing. Some of these yokes have failed in both particulars, others have been successful. Fig. 1 represents the yoke which was used on the Clay Street Hill road in San Francisco by Mr. Hallidie: they were of cast iron, placed about 3 feet apart, and flanged to receive 2-inch planks which formed the conduit. Five years later this yoke was substituted by one shown in Fig. 2, also of cast iron, and thoroughly bedded in concrete, the entire conduit being formed of the same material. The Sutter Street road as first constructed had a similar yoke to that used by the Clay Street Hill road, see Fig. 1; but afterwards the yokes were made of old rails bent into form as shown in Fig. 3, with horizontal "T" iron and braces to support the slot rail.

The California Street road, also of San Francisco, adopted this yoke, built in concrete, the tube being formed of the same material. The

Fig. 1.



Market Street road also adopted a yoke made of old rails, but modified somewhat in form; the conduit of the road was also made of concrete.

Fig. 4 represents yoke of cast iron as used by the Kansas City Cable Railway Co.; it is bedded in concrete, and the conduit is made of the same material, which seems to give good results.

Fig. 5 represents yoke of cast iron, as used by the Metropolitan Street Railway Co., of Kansas City; it has a depth of 8 inches at centre, also thickened at same place; it also has adjustable malleable iron brackets to support and adjust the slot rails.

Fig. 6 represents yoke of cast iron now being used in Denver, Col., by Mr. Harry M. Lane, for the Denver Tramway Co., it is 12 inches deep at bottom, and from several tests made at Watertown, it seems to possess special rigidity to prevent the slot from closing.

Reviewing the various forms of yokes shown, it will be seen that Figs. 1 and 3 have practically no strength at the bottom to prevent slot

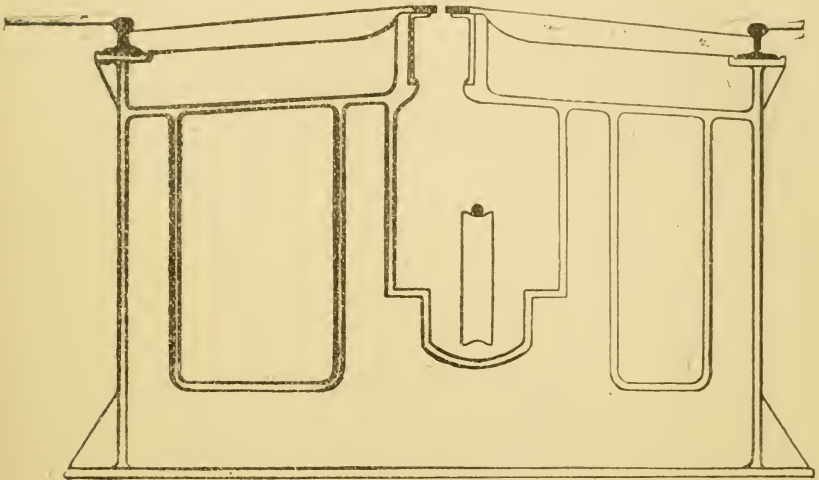
from closing. Figs. 2, 4, 5 and 6 are all improvements in that direction and have been doing good service.

Ordinary rails, side bearing rails, and the Johnson centre bearing rail have all been used on cable railways, the latter possessing advantages that none of the other sections have.

Slot rails are quite varied in section to suit the peculiar form of conduit and yoke and method of adjusting slot when such provisions are made.

It is preferable to fill between the paving stones between slot and track rail with pitch or some other water proof cement to prevent ice from forming and forcing the stones and thus closing the slot. I am convinced

Fig. 2.



that there has been more slot closing from neglect to fill between the paving stones in track than from any other cause.

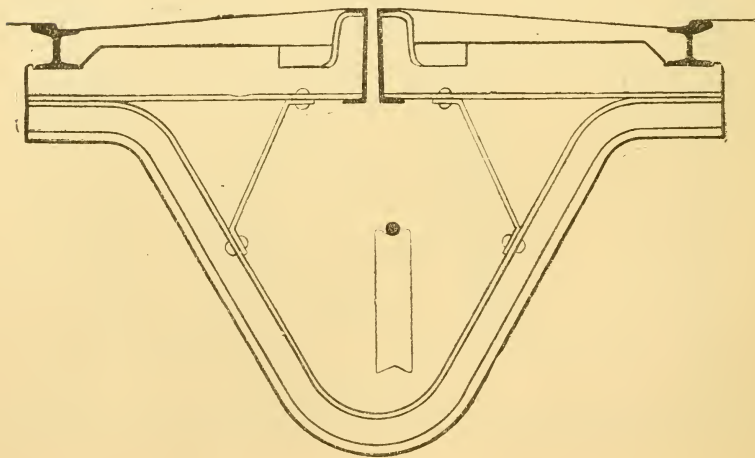
A cable railroad bed must be well made; cheap cement and concrete work has proven dear in the end; when properly made with proper yokes, slot and track rails, the alignment can be preserved indefinitely, when rail after rail has been worn away.

In connection with roadbed I may speak of carrying and curve pulleys, although they are a part of the mechanical work of a cable railway. Fig. 7* represents a carrier pulley, much in form and size as usually adopted; they are generally placed on every eighth yoke, each yoke being four feet centres, makes the carrying pulleys about 32 feet apart. There are many devices and methods for making these pulleys noiseless, and lubricating their bearings automatically; babbitt has been cast in a groove around the pulley to prevent noise and wear on cable;

* Not reproduced.

I scarcely need say that the babbitt wore away soon, and the sheave was useless until renewed again, which would cost as much as a new iron pulley; soft iron pulleys also wear away very fast. There seems to be no alternative for those pulleys but to chill them for service and deaden the noise in some way. One plan has been to secure the pulley frame in the concrete between the yokes so that it has no connection with the metals of the road; this, however, does not prevent the inherent troubles of these pulleys making noise while in motion. The pulley shown here has been fairly successful in this particular; it is cast with three arms to relieve strain, and in two halves with continuous chills to prevent cross fins in chilling, which in the ordinary pulley are seldom ground off and often nick the cable in their revolutions thousands of times in a

Fig. 3.



day. The two halves forming pulley are secured together by threaded screws in both pieces, and riveted with cardboard in between them to deaden the noise.

The box has a grease cup bored out with a neatly fitting plug with a cover to keep dirt from same. The plug and cover form a weight to press grease to a small hole in cup, through using a grease of proper consistency, to press same to bearing as required. These grease cups have lasted several weeks with one filling. In the ordinary way of oiling a cable road it takes four men and an oil refinery to keep them going.

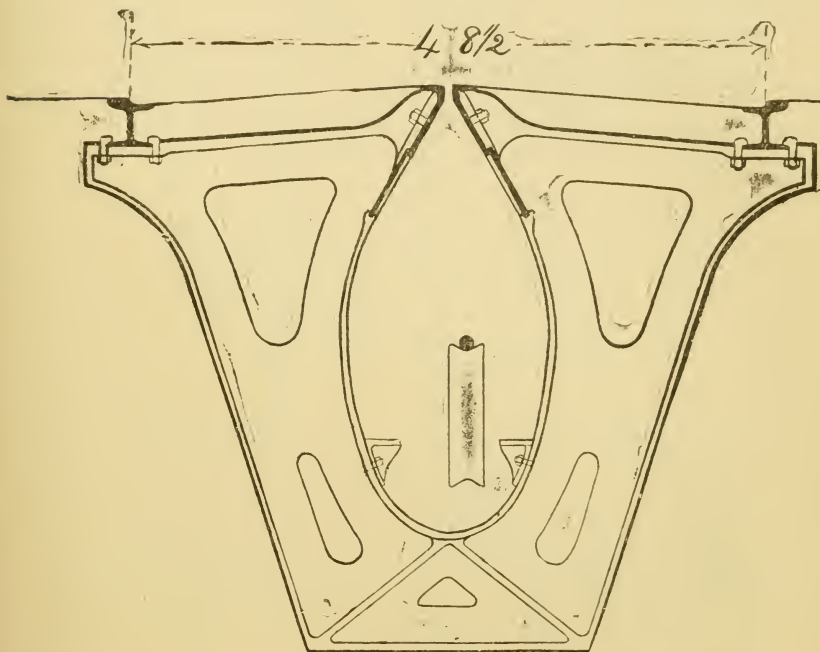
Curve pulleys have been made from 13 to 36 inches in diameter; their number and distance from centre to centre in a curve will depend entirely on their size. It is needless to say that curve pulleys too small in diameter need much attention, oiling and renewing boxes on account of their high speed.

It has been, and I believe still is, the prevailing custom to provide

these pulleys with a bottom flange (see Fig. 8) to support the cable in passing around the curve. As the cable rests on this flange and presses toward body of pulley, it is not long before the flange begins to chafe the cable severely. (See Fig. 9.)

To obviate this the Metropolitan Street Railway Company, of Kansas City, introduced a curve pulley without flange, and supported the cable on carrier pulleys placed between the curve pulleys at intervals around the curve. (See Figs. 10 and 11.) This system seems to be quite successful, and certainly dispenses with the chafing and destruction of the cable in the manner spoken of. This company had occasion to construct a curve

Fig. 4.



on a grade, and found that after the descending car passed the curve it would invariably leave the cable in an elevated and dangerous position. To obviate this, three curve pulleys of same size and shape as the others were provided, with a spiral groove terminating in the regular parallel groove. This spiral, with the revolutions of the pulley, lowers the cable gradually to its regular position without the slightest chafing or injury to the cable.

In connection with road-beds, I might introduce end pits, crossings, "let go" and "pick up" pulleys, depression pulleys, etc., etc., but time will prevent me to-night.

We now proceed to machinery and motive power. In these particulars

Fig. 5.

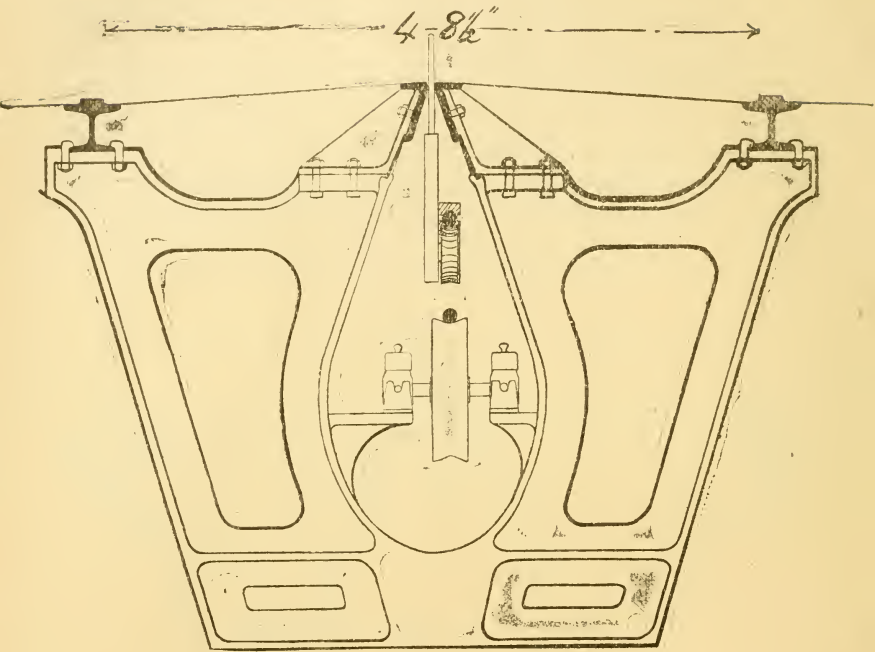
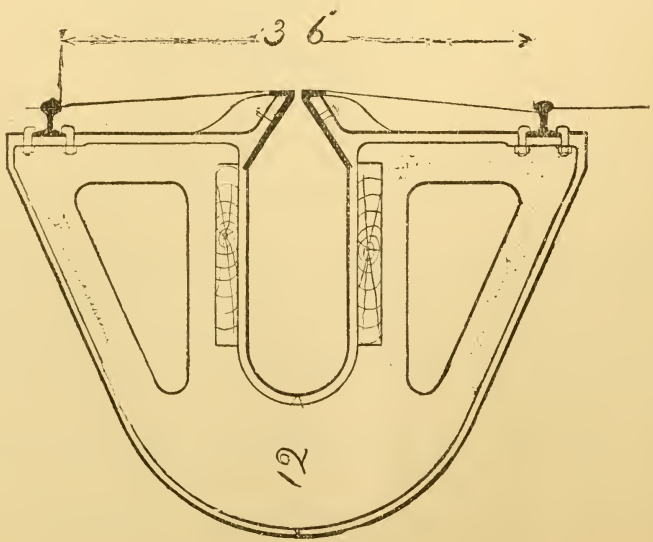


Fig. 6.



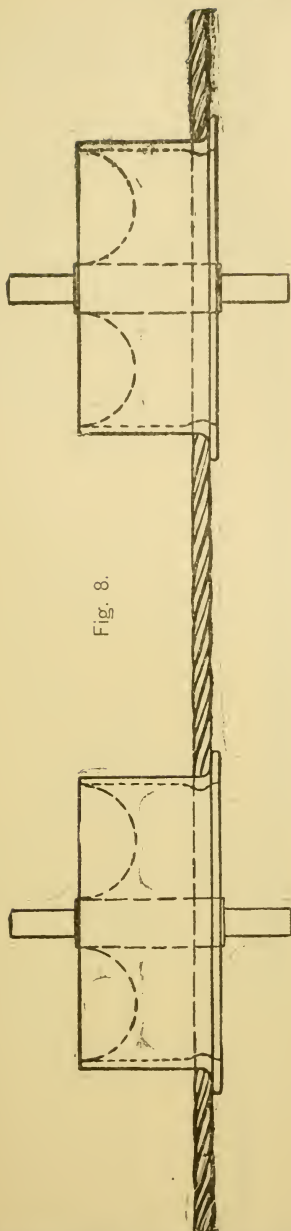


Fig. 8.

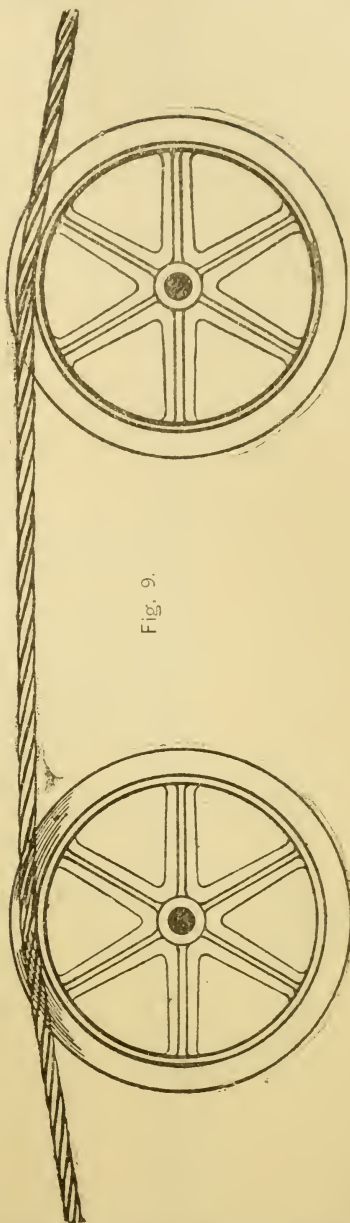


Fig. 9.

the demands of cable railways have caused more radical changes than in any other part of the equipment. Since Hallidie built the Clay street hill road, using an engine 14 inches by 28 inches, we find a gradual and steady increase of power needed, until at present we have plants of 1,000 and 1,500 H. P., with 28 inch by 60 inch and 30 inch by 72 inch engines.

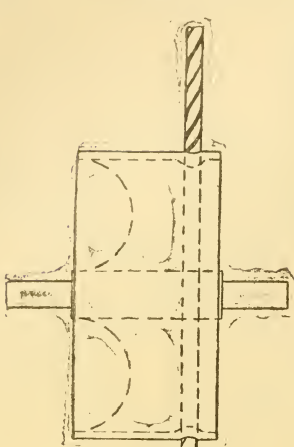


Fig. 10.

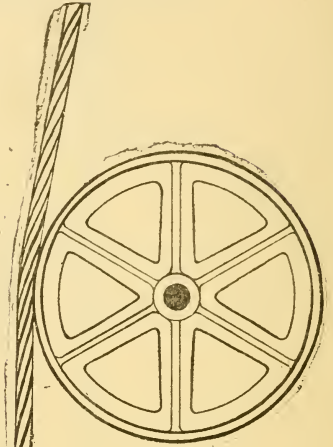
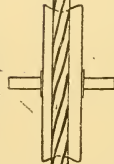
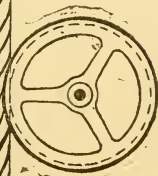
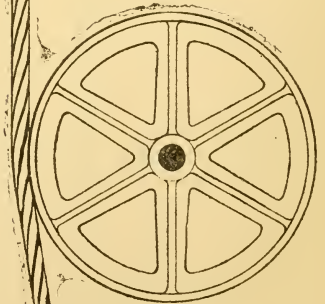
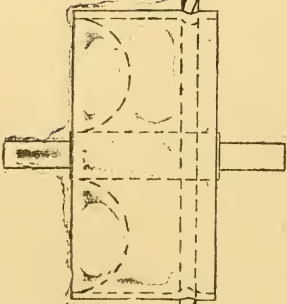
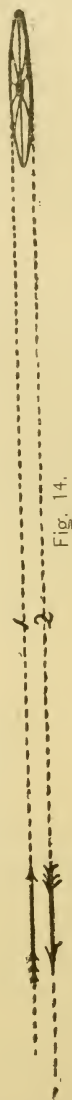
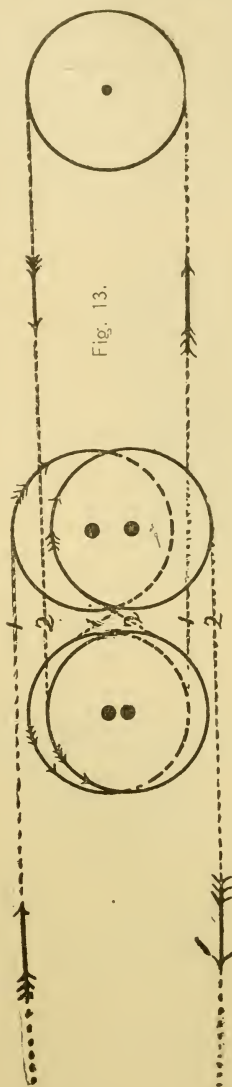
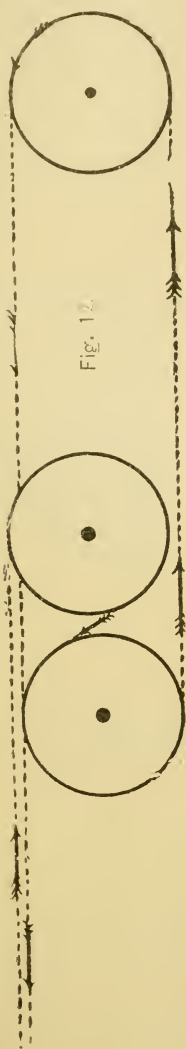


Fig. 11.



It is worthy of note that the fly-wheel of the St. Louis Cable & Western Railway Company's new plant in St. Louis, just completed, is heavier than the entire plant of the Clay Street Hill road, where cars weighing 2,800 pounds, and grip cars weighing 2,850 pounds, and seating fourteen and sixteen persons respectively, and seven such trains was the capacity

of the road ; we are now hauling cars weighing 8,000 to 9,000 pounds, and grip cars weighing 5,000 to 6,000 pounds, seating respectively forty and twenty-two persons, and running sixteen to twenty-six trains made



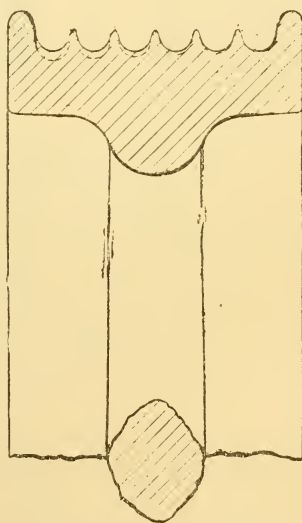
up of these cars and grips. This comparison will give you some idea of the increased demand on engines and machinery. The engines used in cable railway plants are almost exclusively of the Corliss type, this class of engine being well adapted for a variable load, such as is only known in the operation of cable machinery.

An indispensable adjunct to the engines is a heavy fly wheel, which very much lessens the jerking of the cars.

There are many different plans and arrangements of machinery for propelling the cable. The Clay Street Hill road, and Union Street, or Ferries road, San Francisco, used drums with clips inserted in such manner that the greater the strain the greater the clip would compress the cable; these drums had single grooves, and no doubt answered well for a limited length of cable, and a limited number of trains.

The Sutter Street road, of San Francisco, used drums with grooves made of wood inserted into a regular iron rim, and in connection with same used what is known as the figure 8 method (See Fig. 12.) The method is known as the figure 8, although the wrap only makes a par-

H Fig. 15.



tial form of that figure, this arrangement of machinery and cable having only one wrap, and not being able to make any more without chafing the cable, has the disadvantage of having to cut the cable to take it up after tension carriage has run the length of its track. Some time ago I had occasion to investigate this figure 8 system, and discovered that it was possible to get two partial figure 8 wraps on same pair of drums. (See Fig. 13.) The lines of cable marked 1, 1, 1, and 2, 2, 2, respectively, are directly over one another, [as shown in Fig. 14, with tension carriage sheave tilted; the lines 1, 1, 1, and 2, 2, 2, respectively, occupy corresponding grooves on each drum; while this would be very desirable in driving, we are still unable to take up cable without cutting and splicing the same shorter.

The Geary Street road was the first to use a drum with a number of grooves cut in the solid metal (see Fig. 15), and rely on the friction or tractive power of the cable in the grooves, the wraps being made to suit the requirements of the road; this is the kind of drum that has been

commonly used since. Experience, however, has developed the fact that these drums gradually become defective on account of wear in the grooves, and with two to three years' service must be renewed or the grooves re-turned to proper sizes; in the meantime, the gradual wear of the grooves has made a very perceptible difference in their circumference, and consequently a corresponding slippage of the cable in the groove and a very unequal tension of the cable while on the drum absorbing a great amount of power. The writer was never more convinced of this fact than when paying a visit to the Ninth street power station of the Kansas City Railway, Kansas City, Mo., when the friction of the cable from inequality of grooves became so great as to rasp the groove

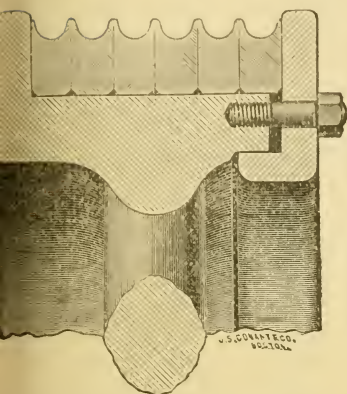


Fig. 17.

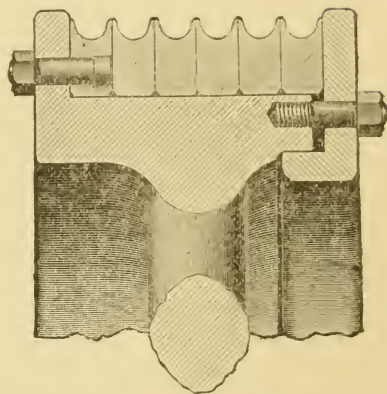
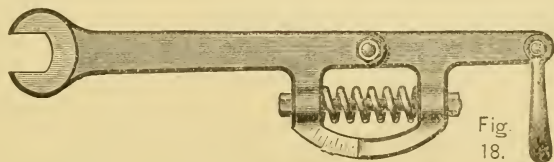


Fig. 16.

Fig.
18.

as with an immense file, sending sparks of heated iron in the form of fire; this caused the drum to break in two between the arms.

Some time prior to this I had devised the differential drum shown in Figs. 16 and 17, which seems to meet all the difficulties found in the solid drum.

Fig. 16 is a section of the leading or driving drum; it is accurately turned to receive six wrought iron rings, one of which is secured to rim of drum, and the other five rings are all loose to move; the drum is provided with a loose flange, held in place and adjusted sidewise with studs to friction rings to the desired amount of driving we wish to do. This tightening is accomplished by a self-registering wrench, see Fig. 18, which makes a very simple and intelligent method of adjusting the required amount of friction, at the same time getting the friction

equal around the entire circumference. A pull of 120 pounds on the wrench on 1 inch studs will clamp the rings so tight that the cable will not move them; that is, the cable will slip in the grooves before it will move the

Fig. 19.

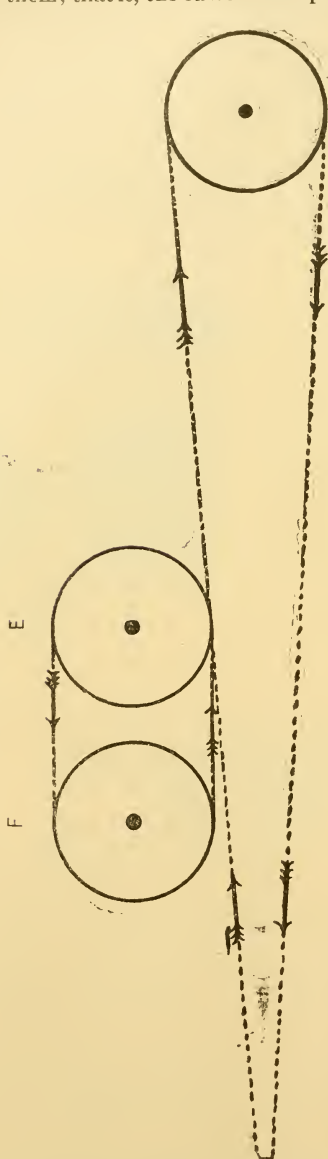
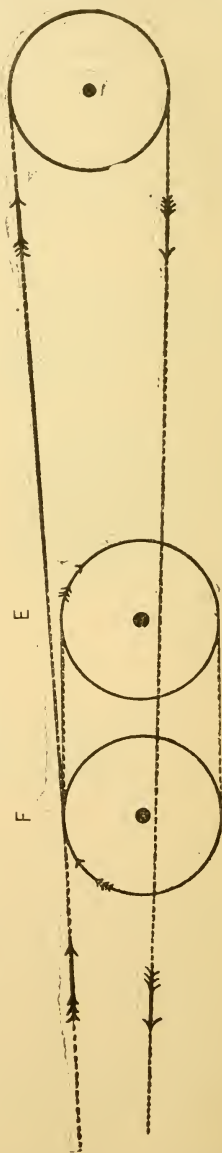


Fig. 20.



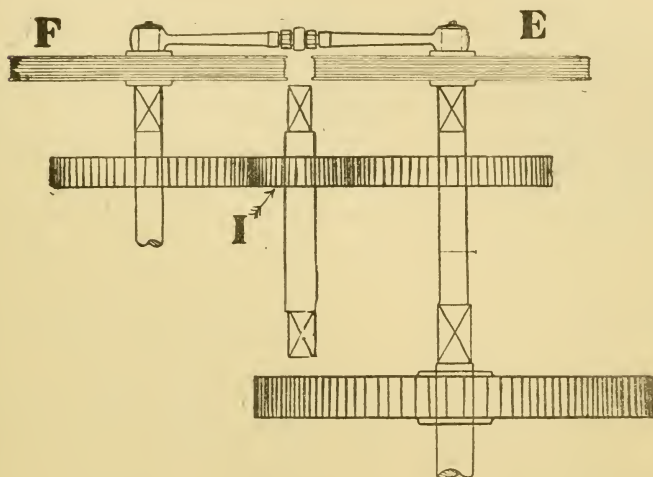
rings; from 30 pounds to 60 pounds on the wrench will give sufficient friction to drive and yet allow the cable to adjust the rings automatically without injury to itself. There are two practical ways of knowing when

the rings are adjusting themselves; first, the impression of cable will be left in the tar in the bottom of grooves, showing no slippage of cable; second, there will be no trembling of any of the wraps while passing from one drum to the other; they will all be tight and resemble bars of iron.

In no case is it necessary for the frictional driving on each ring to exceed $\frac{1}{16}$ of the strength of the cable, hence it is easily understood that the cable cannot be unduly strained while on the adjustable rings.

In practice we find that the rings do their work and move or adjust admirably under the conditions just named; it is questionable, however, as to whether side friction is needed at all as the diametrical fric-

Fig. 21.



tion of the cable in the groove is transferred to the bottom of the ring, which decreases or increases with the load.

Fig. 17 is a section of end drum, exactly the same as the leading drum, with the exception that all the rings are loose. By this system of loose rings it will be seen that the drums are differential in their relation to each other; also that the rings on each drum are differential to one another. With this arrangement it will be understood that when the cable is wrapped from one drum to the other it will be impossible to have any undue strain on any of the wraps; in fact, the cable will not commence to pull the load until each wrap has its portion of the load, thus equalizing the strain on the wraps, a feature impossible to accomplish on a drum with solid grooves.

The manner of applying cable to this class of drum is shown in Fig. 19, when circumstances admit of machinery being placed above street level, and tension carriage being placed below machinery floor. If it is

desirable to place machinery in a basement, and tension carriage on machinery floor, then by placing the drums below, the cable will occupy positions as shown in Fig. 20.

Now by proper winding of the cable on the rings we get two continuous wraps, and when the cable is tensioned with the load the friction with the fixed ring will propel the cable; at the same time the loose rings will adjust themselves to any undue tension or any inequality in their diameters.

It has been customary in this class of plant with solid drums to drive the end drum *F* with gearing from the main line shaft, see Fig. 21, to get the tractive power of the cable in the end drum grooves; this is a very desirable arrangement if it were possible to make and keep the grooves in solid drums exactly the same diameter. The experience just recited shows that if the grooves were made practically the same diameter, it is not long before they wear to different diameters, as shown by dotted line on Fig. 15, the greatest wear being at the incoming groove, and gradually lessening in each groove used. It will be obvious that when these grooves are worn, there will be undue tension and slippage of the cable in the grooves to the extent of that wear, so that it is fair to presume that when the first or incoming groove *H*, Fig. 15, is worn one-fourth of an inch less in diameter than its neighbor, there will be a difference of three-fourths of an inch in circumference; this difference can only be accommodated by the cable slipping three-fourths of an inch every revolution on the groove already too small, or stretching the cable that much.

It would be impossible to stretch the cable three-fourths of an

inch every revolution of the drum, hence we are driven to the more feasible conclusion that the greater part of this difference is taken up by the rope being propelled forward on the smaller groove, ab-

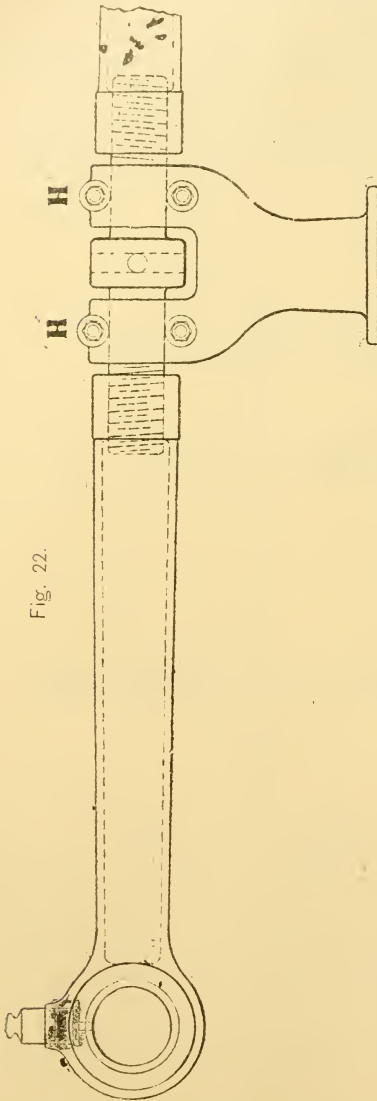
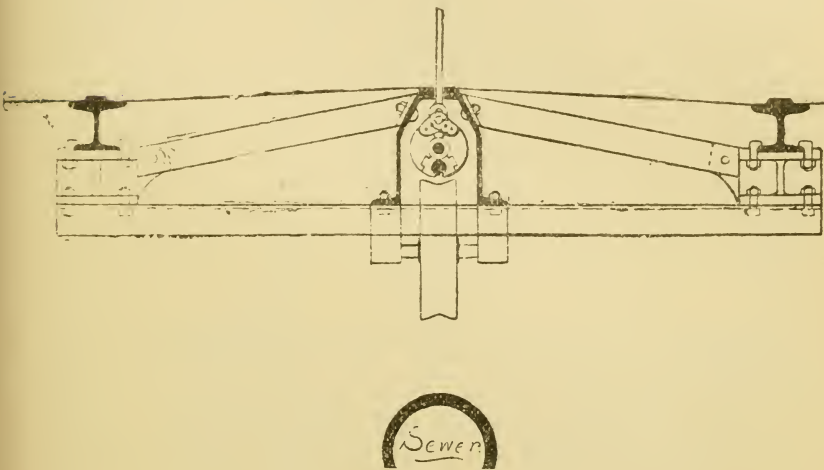


Fig. 22.

sorbing a considerable amount of power. It will be apparent that the more these grooves wear the more they will wear, since the difference in diameters increases as the wear continues : now when the drums are worn, as explained, and they are geared together, it will be obvious that there will be a confliction between the positive drive of the gears and the cable when on different diameter grooves. A test of horse-power was made at the Fifth Street Power House, Kansas City, Mo., some time ago, the engines being indicated prior to removing the intermediate pinion *I* connecting drum gears, and then indicating after pinion had been removed ; the road being under similar conditions at each test, a saving of 35 horse-power was shown when the pinion was left out. The drums had been in use eighteen months, and would therefore be worn; had the drums

Fig. 25.



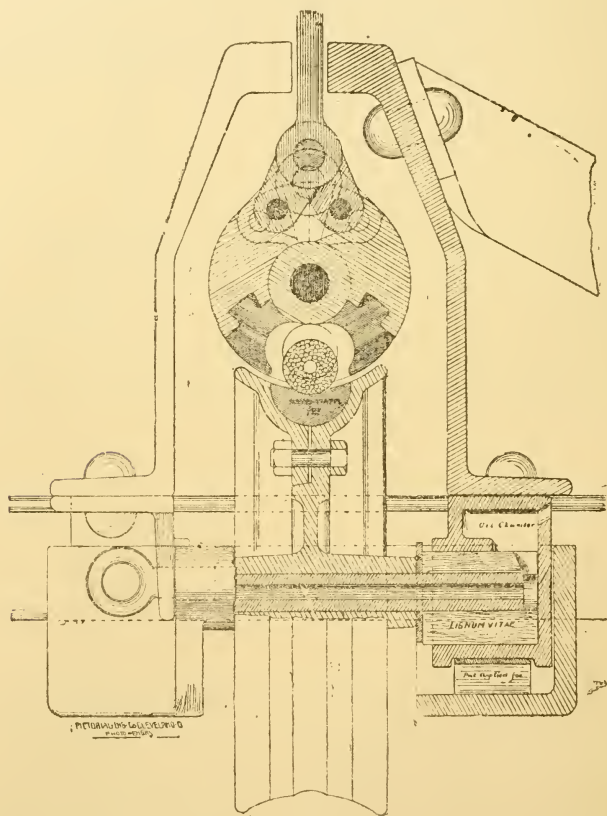
been perfect when second test was made there is no doubt but that a greater difference than 35 horse-power would have been shown.

The Grand Avenue Railway Company, of Kansas City, wisely left off the drum gears as the best solution in the use of solid drums. Other plants have been built since without drum gears at all; this, however, in my opinion, is a very questionable method of driving a cable. As the cable is by far the most severely taxed member of a cable road, it is in my mind the best policy to relieve it of some of its enormous duty instead of taxing it to drive the end drum or idler, as it is called, when not geared. The mere revolving of an end drum and its shaft would not be much, but when we add to this the enormous friction caused by the wraps of cable on the drums we certainly are taxing the cable unmercifully and unnecessarily; this, however, is not the only fault, for since the end drum is not driven it requires just as many more wraps on the leading drum to accomplish the same work. I think it will be apparent to all that with the differential drums geared together and with no

confliction between the gears and cable, but an automatic adjustable movement of the rings carrying the cable, that it will only be necessary to use half the amount of wraps when compared with the method of driving end drum with cable, for in the one case the cable drives the end drum, and in the other the end drum is used to drive the cable.

The strut, as it is commonly called, see Fig. 22, is an essential feature in cable plants using the loop system; it affords support between the

Fig. 26.



two drum shafts at the outer ends, instead of outer bearings; by this arrangement the cable can be taken up without cutting after the tension carriage has run the length of its track. Heretofore these struts have been made to adjust lengthwise with a taper key; the strut shown has a right and left screw operated by a lever and the adjustment can be felt to a nicety; after adjustment the bolts *HH* are tightened on the screw to secure same from turning.

Grips have always been a conundrum in cable railroads as well as in "lodges." In cable railways, however, there are only two kind, a

“bottom grip” and a “side grip,” the former taking the cable from below and the latter taking the cable from the side.

In the construction of a road it is necessary to decide what kind of a grip will be most suited, each grip having its peculiar advantages. Where many crossings have to be made under existing cables, the bottom grip seems to have some advantages in dispensing with reflections in the rails, etc. Root side grip is extensively used.

To describe the various grips would occupy too much time; however, in a general way, a grip has a lever coming through the car, convenient to the operator; it is usually coupled to compound levers or toggle movement to operate the jaws, which are closed or opened at will. A sector with teeth and pawl is provided to hold the lever in place when grip is secured to cable. The grip can be adjusted to run car at the same speed as cable, or at a less speed when occasion may require. Removable dies are placed in the jaws of grip; they have been made of almost every known metal, and even wood has been tried for grip dies. The softest dies I have seen were made of copper; the hardest were of tool steel hardened. There is no doubt but that this latter material will do good service if the dies are not too expensive to make. Hard bronze has been giving good satisfaction, both in service and on cables; these are not as expensive as at first supposed; they can be bought for eighteen cents (18c.) per pound, and credited when returned worn at twelve cents (12c.) per pound, leaving a difference of six cents (6c.) per pound on the weight of the old dies, and 18c. a pound for the amount worn off, which is about one and a half pounds, making a total expense of 95c. These dies usually last a week to ten days.

Fig. 25 is a section of Vogle & Whelan's shallow conduit cable roadbed. This is undoubtedly the smallest conduit that has ever been devised. It is about 9 inches deep and 6 inches wide inside, and formed of a special section of rolled iron. The sleepers are preferably of iron; the rails are supported on chairs to bring them to the proper height; the conduit iron is held securely to chair to prevent slot closing. The carrier pulley is secured to conduit iron, thus preserving a regular depth and alignment, and is accessible through manholes between slot and rail. The manholes are connected from one to another by a sewer at the bottom, thus keeping the cable freer from refuse and grit than when a large conduit is used for the cable and to act as a sewer at the same time.

This small conduit has been made possible by Mr. Vogle's ingenious bottom grip, fig. 26. The body of the grip is round, with spherical ends shaped to throw off a strand. The small levers hinged to the rotating parts of body form a powerful toggle joint. The dies are inserted in dovetail slots, and held in place by the spherical end caps. The grip body runs within half an inch of the carrying sheave, and cable can be taken as easily over a carrying sheave as between carrying sheaves. The depressing frame to which the grip is attached is supported on grip-car with springs to carry its weight, and can be depressed three or four inches in descending for the cable, but as the deflection of cable between carrier pulleys seldom exceeds one inch, the operator has but little trouble in getting the cable.

I understand that a road of this kind has been built in Tacoma, W. T., and arrangements are being made to build others. The figure shown is the all iron construction, and can be built for \$30,000 per mile and \$40 per foot extra for curves. A wooden construction for suburban roads can be built for \$20,000 per mile. These figures compare favorably with the regular deep conduit system, which costs from \$80,000 to \$100,000 per mile and \$30 per foot extra for curves. Even with this enormous cost a cable road can be operated as economically as with horses with a traffic of 4,000 passengers daily ; and for every increase above this there is an increase of profits in favor of the cable road, as the operating expenses are not near as much in proportion as on horse car roads with a traffic exceeding 4,000. I inquired recently from the manager of a comparatively new cable road for the percentages of receipts for operating and maintenance of road. His answer was 70 per cent. of receipts for operating and 11 per cent. for maintenance; expenses will be but little more when travel is doubled.

It has been a noteworthy fact that a cable railroad has always improved property along its line, and especially so when it runs through suburban property. The projectors of cable railroads into suburban districts have been public benefactors, making it possible for business men and working men to live in the suburbs, and yet get to their places of business in quick time.

I trust that the time is at hand when Cleveland will come to the front with cable railroads running in every direction. Our streets are well adapted, the need is apparent, and we await a public benefactor.

DISCUSSION.

Mr. Holden : Does the \$30,000 a mile you mention include power, or simply the construction of the road ?

Mr. Walker : That amount is for the construction of a mile of single track with necessary pulleys : it does not include power plant.

Mr. Holden : What additional amount would be required for power on a four mile road, for instance ?

Mr. Walker : I think it would be about \$25,000 to \$30,000 a mile additional. This amount would be about the same whether the regular road-bed, or the Vogel and Whelan system was used.

Mr. Sargent : Is it not necessary to have a double-track road ?

Mr. Walker : Yes, sir ; I spoke of the single-track road with reference only to its cost.

Mr. Searles : The question of drums has been very interesting to me because the wearing of the grooves in the drum has been one of the greatest difficulties connected with the operation of cable roads. I am favorably impressed with these friction rings; it would seem as if they would obviate the difficulties arising from unequal diameters of grooves. The driving friction is on the sides of these rings, yet it occurs to me, nevertheless, that there will still be considerable friction between the rings and the solid drum, and that will tend to a loosening of the rings on the drum. I would like Mr. Walker to state if he has made provision for meeting that difficulty. When he first used the word "adjustable" I thought he referred to the adjustment of the diameters, but I see that

he means the amount of friction on the sides. If there is no break in the rings they will be loose on the drums, or with one they will close on the drums and be a little smaller in diameter. I think we shall not have a perfect working system till we can maintain uniform diameters.

Mr. Walker: I do not lay much stress on the side friction, I rely more on the diametrical friction. We will suppose that the rings are entirely free sidewise, we increase or decrease the diametrical friction with every car we put on or off, making the amount of friction, consequently the power, according to the resistance. Hence I believe the drum would drive without side friction; I prefer, however, a little side friction, but nothing like an amount that would damage the cable by preventing the rings from turning.

Mr. Holden: How do you know that the cable does not slide on the ring, as it does on the groove?

Mr. Walker: There are two ways of knowing when the cables are adjusting themselves with the rings. First, when the cable slips in the grooves of solid drums, the wraps that pass from one drum to another can be seen to vibrate; when the rings are adjusting themselves on differential drums, the cable, forming wraps from one drum to the other, resembles solid bars of iron. Second, when the cable slips in the grooves of solid drums the grooves will be smooth and bright. In the differential drums the cable leaves its imprint in the tar left in the groove of the ring.

I think these two features give evidence of the adjustability of the rings.

General Leggett: The friction of these rings on the drum tends to wear the inside of them. How is that remedied?

Mr. Walker: I do not anticipate more wear on the inside surface than on an ordinary bearing. Of course there will be some wear, but even if there is the rings will go on adjusting themselves and not damage the cable.

Mr. Whitelaw: Is it intended to renew the rings or the drum itself?

Mr. Walker: The rings would be the simplest and much the cheapest to renew.

Mr. Searles: If there was considerable wear after a time the rings would be partly separated from the drum; there would finally be a sort of inner rolling motion; in other words, there would not be complete contact around the semicircle.

Mr. Walker: This would, no doubt, be true if wear was excessive and the rings were rigid; their large diameter, however, will allow them to spring enough to obviate a rolling motion; they can never wear to that extent. I omitted to speak of the lubrication of these rings. There are five large grease cups that keep a constant lubrication; I have seen the grease work out between the rings while the drums were in motion.

Mr. Rawson: How much slipping have you observed?

Mr. Walker: In our first experiment at Twelfth street we made some small holes in the rings and inserted pins; with friction drawn up to 120 pounds on the wrench, we found there was no motion at all in the rings. We weakened the pull on wrench until we found where they would move. The rings would not always move in one direction, showing that

there is a good deal of stretch in the cable as it is wound on the drum. The rings sometimes go forward and sometimes backward ; some would actually reverse the motion again. That proved to me that the cable was wound on the drums with different tensions, and the rings responded to the varying resistance of the road.

We have found that a low side friction or pressure is best ; the wraps of cable passing from one drum to the other will be steadier and stiffer at 30 pounds on the wrench than at 60 pounds.

Mr. Searles: Is that road in Tacoma in operation with this new conduit?

Mr. Walker: I could not say. It was building three months ago, and on the wood sleeper plan. Mr. Vogle is a Californian, and is quite a cable engineer, and I have every faith in his work.

Mr. Searles: The difficulty is that the clearance is so small that the grip might touch the conduit with the jolting of the car.

Mr. Walker: Mr. Vogle has about one inch clearance in conduit at sides for his grip, whereas the shank of grip has only the usual clearance in slot. He dispenses with guard rails in passing round a curve, as the conduit iron where slot is formed is thickened to answer the purpose of a guard rail.

Mr. Searles: Is there no floor to that conduit?

Mr. Walker: There is no floor shown; it can be made of bricks, concrete, or an iron plate can be laid under conduit iron between ties. The water that goes into the slot passes into manholes at each carrier pulley, then to the sewer below

Mr. Searles: The conduit is about the same size as Johnson's.

Mr. Walker: I think it is; Mr. Johnson's I think is a little wider.

Mr. Searles: They both stand on top of the ties.

Mr. Walker: Yes, sir.

A Voice: What distance apart are the studs on driving drum?

Mr. Walker: About 1 foot 9 inches to 2 feet. There are 28 in a 16 foot, 24 in a 14 foot, and 20 in a 12 foot drum.

Mr. Whitelaw: Do they use a double flange wheel?

Mr. Walker: No, sir; that is simply for centre bearing on the rail, the ordinary wheel being used. I noticed in St. Louis with the side bearing rail they had filled under outer flange with wood; after a year or two of service it was no good, being rotten.

Mr. Searles: I found in the St. Louis old plant, when the engine was first started, there was great difficulty on account of unequal motion between the cable and the gears. The pinion in St. Louis was dispensed with; I should think there would be no necessity for dispensing with it with those adjustable rings, while there would be great advantage in keeping it in.

Mr. Walker: I think it is only a question of time when cable engineers will adopt the differential drum and put gears in again.

Mr. Searles: Have you card records to tell what horse-power it takes to drive this machinery without the cars?

Mr. Walker: On the St. Louis & Western Railway it requires 185 horse-power to propel the cable alone at 8 miles per hour. There are slight grades varying from one to five per cent. There are 13 double curves on

the road, 26 in all ; some of these curves are only 29 feet 6 inches radii, and consequently there is much loss of power in turning them. Twenty cars composed of grip car and regular cars; weighing 5,000 pounds and 8,500 respectively, passengers additional, would take from 180 horse-power to 190 horse-power, making 9 to $9\frac{1}{2}$ horse-power per train. When this data was taken the road was under ordinary condition and traffic. The cable was 34,600 feet long and $1\frac{1}{4}$ inches diameter ; this cable was the longest ever operated in one piece. Since new machinery has been supplied it has been made into two lengths. The Fifth street cable road, Kansas City, Mo., referred to in the paper, takes about 120 horse-power to propel the cables alone at eight miles per hour ; the road had few curves and grades ; the steepest, however, being about seven per cent. Twenty trains of grip car and regular car with passengers would indicate about 280 horse-power; deducting the 120 horse-power for propelling empty cable, would leave about 8 horse-power per train of grip and car. When President Cleveland was in Kansas City, the traffic was much increased ; the engines indicated 484 horse-power for 22 trains, making 16 horse-power per train, allowing 120 horse-power for moving empty cable as before. It will be seen that there is more economy in horse-power in running the cable with heavy traffic than light, as the frictional resistance of the cable is not in proportion to the amount of traffic carried. The combined length of the two cables is about 40,000 feet.

Mr. Searles : What is the difference in power required to drive machinery between the ordinary solid drum and the drum supplied with these rings ?

Mr. Walker : I have not got the data yet on this point. I think, however, that the illustration mentioned in the paper shows conclusively that there is great loss of power in running solid drums when they are worn.

Mr. Searles : As near as I can gather, the horse-power required to move machinery alone is about 11 horse-power per mile, modified, of course, by the curves.

Mr. Walker : Eleven horse-power may be sufficient for straight roads, but would not be sufficient for a road with many grades or curves; approximate estimates only can be made for the horse-power of cable railways, even from the most carefully prepared profiles. The engine indicator is the final source of evidence. There is one feature, however, in cable railways that generally escapes notice, that going up grades of 14 or even 20 per cent. is not so destructive to the cable as making right angle curves. This is contrary to the general impression, but is easily understood when the line of cable in curve is compared with line of excessive grade. The cable going up a grade of even 20 per cent. passes through no such contortion as in a curve. It is also very questionable whether the tensile strength of a cable is tested as much on a 20 per cent. grade as it is in a curve of say 40 feet radii.

Mr. Rawson : What devices have they for indicating loose strands ?

Mr. Walker : There is what is called a strand indicator, a device electrically connected so that when any enlargement of the cable moves an arm it will ring the signal at the engineer's desk ; it is placed on the incoming cable so that strand may be cut off or fixed before leaving the machinery room.

Mr. Rawson : May not a strand develop itself going out and travel seven or eight miles?

Mr. Walker : That might occur. There are signals along the road to announce to the engine man at once anything that happens on the road. The strand signal can be placed at the end of the road, if it is a switch terminal, as well as at the power house. A strand may be from 50 to 1,000 feet or more long, but they are generally cut off before much damage is done. A cable can run a long time without one strand without injury to the cable; at night they stop and put in the strand or whatever is required to repair the cable. They can put in about 1,000 feet of strand, or splice a cable, in about four hours.

Mr. Whitelaw : About what is the life of one of these cables?

Mr. Walker : The shortest I have known was about four days; the longest about eighteen months. They usually last from six to eighteen months.

Mr. Mordecai : How often would they have to stop for repairs with a good plant?

Mr. Walker : Sometimes they run four months without the slightest stoppage. The St. Louis Cable & Western road lately made a run of three months without stoppage; they had a mixed cable of three pieces, about 19,000 feet being new. I believe with our differential drums and new machinery the cables will last much longer than before.

Mr. Mordecai : What was the trouble in Market street, Philadelphia?

Mr. Walker : I think the principal trouble was the slot closing. The machinery was built by Wetherell, of Chester, Pa. He had an arrangement for a differential movement, but it is differential in one part only, it does not act on all the wraps.

Mr. Rawson : What provisions are now made for stoppages?

Mr. Walker : Some companies keep a few horses in stock, but repairs are made so quickly now that it is very rare to have any accident happen that cannot be put right in a few minutes.

Mr. Swasey : Mr. Hallidie said that with modern arrangements a cable could now stand about two years. One quite notable feature in using belts from the engine to the main driving shaft, Mr. Hallidie said, was that it was easier for the cars with the belt than with the gears, you felt less jar.

Mr. Walker : The life of a cable has been very much shortened by the attempt to run too long roads. Engineers seemed to try to outdo one another in the length of road. Thirty-four thousand six hundred feet was the length of the St. Louis Cable & Western Railway's. It was the longest cable in the world; it has now been cut in two. The length of the cable should not exceed 25,000 feet.

Mr. Searles : A straight line might be worked 35,000 feet, but the curves increase the difficulty.

Mr. Walker : The curves and grades must always be taken into consideration.

Mr. Rawson : How would you adjust that?

Mr. Walker : We built a new plant, which was double. We have about 10,000 feet of cable on one end and 24,600 feet on the other.

Mr. Searles : I saw a statement in a paper this week with regard to the

relative expense of cable, electric and horse cars. It was that the expense of an electric road being one, the expense of a horse railroad would be 1.47, and of a cable road about 1.65. An inversion of these figures would be nearer the truth.

Mr. Walker : Chicago has run cable cars at an expense of $11\frac{1}{2}$ cents per mile, as compared with the old service of horse cars at 24 cents per mile.

FIELD-BOOKS.

BY EDWARD BUTTS, MEMBER OF THE ENGINEERS' CLUB OF KANSAS CITY.

[Read March 5, 1888.]

In preparing a paper on the subject of field-books it seems proper to refer back to a time previous to the introduction of that special branch of engineering literature. In the thirteenth edition of a volume entitled "Geodæsia; or, the Art of Surveying," by John Love, printed in New York in 1796, we find the following of the field-book: "You must always have in readiness in the field a little book, in which fairly to insert your angles and lines, which book you may divide by lines into columns, as you shall think convenient in your practice, leaving always a large column to the right hand to put down what remarkable things you may meet with in your way, as ponds, brooks, mills, trees, or the like. You may choose whether you will have any lines or not, if you can write straight and in good order the figures directly one under another. For this I leave you chiefly to your own fancy, for I believe there are scarce two surveyors in England that have exactly the same method for their field notes."

In Hutton's "Mathematics," published in 1833, is the following of the field-book: "In surveying with the theodolite or any other instrument, some sort of a field-book must be used to write down in it a register or account of all that is done or occurs relative to the survey in hand. This book every one contrives and rules as he thinks fittest for himself. Some skillful surveyors now begin at the bottom of the page and write upward."

Worcester's Dictionary, published in 1883, contains the following: "Field-Book (*surveying*). A book used for setting down angles, stations, levels, etc."

Webster's Dictionary, published in 1886, contains the following definition: "Field-Book. A book used in surveying or civil engineering, in which are made entries of measurements taken in the field."

The word field-book does not appear in Walker's Dictionary in 1831, but the word pocket-book is said to mean "a paper book carried in the pocket for hasty notes." This definition of the pocket-book is also given in the latest edition of Worcester's and Webster's dictionaries, which accounts perhaps, to some extent, for the words field-book and pocket-book being often used indiscriminately.

By the foregoing it is obvious were we to rely upon our vocabularies for an understanding of what we term a field-book we would have a very meagre idea of the extent of the meaning of the word, as in addi-

tion to the aforesaid the word field-book means a small book containing formulæ and tables applicable to the location of railroads, principally devoted to the formation of curves. The formulæ and tabulated information contained in the field-book are deductions of geometrical principles established by mathematicians more than two thousand years ago, and were presented at that time by Euclid in a systematic form.

The first application of the method to lay out railroad curves by means of offsets from the tangents and chord is claimed by Mr. T. Baker, of England, who is said to have communicated the method, as early as 1824, to the *Gentleman's Diary* for insertion, but for given reasons it did not appear in that journal until 1837.

As to who first applied the method of laying out railroad curves by means of deflection angles, as practiced at present, Mr. S. H. Long is unquestionably entitled to the credit. His "Railroad Manual, or Brief Exposition of Principles and Deductions Applicable in Tracing the Route of a Railroad" was published in 1829. "The design of this little work," says the author, "is to place in the pocket of the engineer a brief and perspicuous compend of easy rules that may serve as a directory to guide him in tracing the route of a railroad."

This is the first book printed especially for field use. It is divided into two parts ; part one containing one hundred and ten pages, of which fifty-one pages are descriptive of laying out various railroad curves as practiced in the United States at present ; eleven pages on the subject of resistance to locomotion upon curved and inclined railroads, twenty pages on reconnoissance, twenty pages on earthwork, and eight pages on the elevation of the outer rails of curves. Part two contains sixty-two pages, all devoted to mathematical tables as follows: Sub-chords and angles for various radii, three pages ; sub-chords, versed sines and deflections for distances of ten feet for a one degree curve to a fourteen degree and thirty minute curve inclusive, expressed for each thirty minutes of curvature, thirty-one pages ; long chords, ten pages ; distances around curves, four pages ; turnouts, two pages ; arcs, two pages ; roots and squares, six pages ; elevation of outer rails on curves, two pages ; ordinates, two pages. It will be readily seen by the above contents that this book was very similar to the latest published field-books.

"Methods of Location or Modes of Describing and Adjusting Railway Curves and Tangents, as Practiced by the Engineers of Pennsylvania," is the title of the second field-book printed in the United States. It was written by Samuel W. Mifflin in 1837, the second edition of which appeared in 1850, and the third edition in 1854. This book contains forty-eight pages, all, except about four pages, are devoted to curve problems, the solutions of which are made by geometrical diagrams. The method for laying out curves is first to run in a curve and afterwards adjust it to the desired location, never intersecting the two tangents, as is generally the practice now. There is on the forty-eighth page a table of chords, which is the only mathematical table in the book. In the preface, Mr. Mifflin says : "In such a work I consider it of importance to dispense with all difficult calculations, and even with tabular statements which cannot be committed to memory. In this I have fortunately succeeded. There is nothing in the following pages which may not be remembered

by an assistant after a short practice, and executed in the field even if the book be left at home." This work was, no doubt, in its time an excellent addition to the civil engineer's appurtenance, as it has received the approbation of the best engineers of its day. It certainly contains nothing that could be considered superfluous, except, perhaps, the articles on the adjustment of instruments. To dispense with all tabular statements and compel the assistant to memorize all that is required in field practice would hardly apply to the professional advancement of 1854. The book is now out of press, its method of demonstrating problems in field-books having gone entirely into disuse. It is believed that this and Colonel Long's Railroad Manual are the only printed field-books that have gone out of press since the introduction of that branch of literature.

In 1846 there was printed in Berlin a book entitled "A Practical Manual for the Determination and Construction of Railroad Curves," written by B. Brunckow. In the preface of this book we find the statement that previous publications of this kind have been printed in pamphlet form containing tabulated calculations made for angles of whole degrees only. Also, the tables inserted in this volume, in addition to being much more extensive, are carried, in many cases, to four decimals, to give a more correct result in their use. This book is printed in both the German and the French languages. The base of all calculations contained in this volume is the Prussian ruten, reducing the various measurements of fifty-three different European states to that equivalent, which forms Table A, occupying twenty-six pages, and consisting of five hundred and thirty computations. Table B occupies one hundred and ten pages, and consists of sixteen thousand and five hundred computations. These computations consist of tangents, arcs, the shortest distance from the curve to the point of intersection; the shortest distance from the centre of the curve to a point on either tangent. Also, the distance from the last named points to the point of intersection. All calculations in this table are for a radius of one hundred ruten for every alternate or even minute of angle from naught to one hundred and ten degrees. Table C occupies fifteen pages, and consists of distances from the tangents to the curve for every five feet along the tangents for various radii, from fifty to one thousand ruten. There are in this table one thousand one hundred and sixty-seven computations. Table D gives that part of the tangent between the point of intersection and a point on the tangent perpendicular to the radius at the centre of the curve. This table covers thirty-six pages and consists of three thousand three hundred computations. Table E consists of half the chord from the point of curve to the point of tangent, also the perpendicular distance from this chord to the radial point, calculated for a radius of one hundred ruten for every alternate minute of angle from naught to one hundred and ten degrees. Fifty-five pages are devoted to this table, which contains six thousand six hundred computations. Table E plus consists of ordinates for every five feet for various radii from fifty to one thousand ruten. This table covers fifteen pages, and is composed of one thousand one hundred and seventy-three computations. The whole volume is composed of two hundred and seventy-seven pages, which contain

twenty-seven thousand nine hundred and three computations, devoted exclusively to the wants of the locating engineer. This book may well be considered a remarkable production when the date of its publication is considered. It also is remarkable for its treatment of the special subject, *i. e.*, the location of railroads, which is rare for Europe.

The method of laying out curves with offsets and ordinates was the first method to suggest itself to the civil engineer. This practice has long since gone out of use in the United States, having been superseded by the method of measuring and deflecting around the curve. This has also been generally adopted throughout Europe, though the first method is still to some extent in use.

The first edition of the "Engineer's, Contractor's and Surveyor's Pocket Table Book," by J. M. Scribner, appeared in 1847 and the twelfth and last edition in 1887. This book is intended for a "field or office" book. It contains the logarithms of numbers, also logarithmic sines and tangents, the traverse table, table of natural sines for each five minutes, also the same for natural tangents, table of segments of arcs, and the length of circular arcs, explanation of the prismoidal formula, table of excavation and embankment, consisting of eleven tables. Some of these tables are made out for stations sixty-six feet apart, with cuts given in feet and inches; others are made out for stations sixty-six feet apart, with cuts given in feet and tenths, and others are made out for stations one hundred feet apart, with cuts given in feet and tenths. These are followed by tables of arcs of circles, square and cube roots, weight of iron bars, weight of cast-iron pipes, strength of material, etc., etc. "Hints about laying out curves—in laying out curves," says the author, "the following method has the advantage of great accuracy and expedition over that of angles taken by an instrument." The method given is to use chords and offsets calculated in an approximate way. Perhaps in 1847 Mr. Scribner could lay out curves by this method with more accuracy and expedition than by the other method he speaks of, but it cannot be done in 1887.

Hints on curves is followed by tables for ascertaining the superficial quantity of land for railroads and canals, diagrams and explanations of earthwork in canals, tables of board measure, etc., etc., closing the volume with eighteen pages of advertisements. The table of logarithms is about all that this book contains that can be made serviceable to the civil engineer as a field-book.

In 1851 the first edition of the "Field Practice of Laying Out Circular Curves for Railroads," by John C. Trautwine, was published. This book contained seventy-five pages, devoted exclusively to curves, except one page, which gives rules for adjusting the transit instrument. The table of radii, table of ordinates, table of long chords, and the table of natural sines and tangents, comprise the tables found in this book. The table of radii appears the first time in a field-book here; also the method of calculating the various curve problems by means of natural functions. In this volume there are twenty-two pages devoted to about the same number of curve problems. The sixth edition of this work, published in 1869, is the same as the first edition, except it has a few more curve problems, a table of middle ordinates for various lengths of rails, ten pages devoted to the resistance of curves, a table of

actual tangents for a one degree curve, calculated to the nearest foot for each ten minutes from naught to one hundred and twenty degrees. In reference to this table the author remarks: "For the following idea and table we are indebted to Mr. N. F. Jones, Civil Engineer." The principle by which this table is used was given in Mr. Brunckow's Field-Book in 1846.

A table of actual tangents for a 1-degree curve calculated to two decimals, for every minute from 0 to 96 degrees, with instructions to use just as Mr. Trautwine describes in 1869 and 1887 was printed in Mr. Cross's field-book in 1855. The thirteenth and last edition of this book, issued in 1887 contains 192 pages, being nearly twice the number of the preceding editions. There has been added about twenty-five more curve problems, a table of versed sines, 13 pages devoted to the engineer's transit, table of the elevation of outer rails on curves, an article on equation of curvature.

The reason for leaving out all frog or turn-out problems or tables may be explained by the following extract from the preface: "The number of problems might be indefinitely increased by the aid of Euclid or of any good modern work on geometry, but in fact very few are required in actual practice. Any extraordinary ones that may present themselves can be solved by drawing. In preparing his drawing for this purpose the young assistant need not always confine himself to such scales as may be managed by the common dividers, but when, as often happens, only a few chains of a curve need be drawn including turnouts, etc. He may with great ease lay them off on the same principle as in field operations by using his protractor, and either by long chords or by tangential and deflection distances and angles employing a scale of three to twelve, etc., inches to a hundred feet, and filling in the intervals when required by the table of ordinates. Even when the preliminaries of a curve have been found by calculation it generally has to be run two or three times on the ground before it will fit perfectly. Therefore, a resort to a drawing does not necessarily increase the field work." The name "Table of Actual Tangents," given in previous editions, has been changed to "Table of Actual Apex Distances" in this. The articles on the transit, the elevation of the outer rail on curves, also the articles on the resistance of curves and equation of curvature might be termed superfluous matter for the field-book.

The first edition of John B. Henck's "Field-Book for Railroad Engineers" was published early in the year of 1854. The following is an abstract from the preface: "The object of the present work is to supply a want very generally felt by assistant engineers on railroads. Books of convenient form for use in the field, containing the ordinary logarithmic tables, are common enough, but a book combining with these tables others peculiar to railroad work, and especially the necessary formulæ for laying out curves, turnouts, crossings, etc., is yet a desideratum." This is the first printed book that contains the word field-book in its title. Also, here we first find the term tangent applied to the distance between the point of intersection and the point of curve. That which Mifflin and Mr. Trautwine has previously termed in their field-books the tangential angle is here known as

the deflection angle, which is equal to one-half of Mr. Trautwine's deflection angle. This book contains about sixty problems relative to curves, embracing circular curves, reverse curves, compound curves, parabolic curves and turnouts, occupying seventy-seven pages. There are twelve pages devoted to leveling and twenty-three pages devoted to earth work. Followed by tables of radii, long chords, frog angles, properties of materials, magnetic variations, trigonometrical formulæ, square and cube roots, logarithms of numbers, sines and tangents, natural sines and tangents and various grades per mile, making in all two hundred and forty-three pages. The book retained its original form until 1882, when an appendix of twenty pages relative to curves, levels and rail expansion was added, also a table of "tangents and shortest distances from intersection point of a one-degree curve," calculated for each five minutes from one to ninety degrees. The table of properties of materials and the table of magnetic variations have been left out of the last edition, the space they occupied being filled with tables for computing heights by the aneroid barometer. This exchange is generally considered injudicious, speaking specially in reference to the table of magnetic variations. There are forty pages of this book devoted to leveling and earth work, which are an unnecessary appendage to a field-book. Also it is unnecessary for a field-book to contain both the tables of logarithms and natural functions, the former being rarely used, when the latter is obtainable, by the older field engineers.

The first edition of the "Railroad Engineer's Pocket Companion for the Field," by W. Griswold, appeared in 1854, and the last edition in 1883. This book has about twenty-five pages devoted to rules for curves, nine pages to trigonometry and surveying, twenty-nine pages to leveling, and thirteen pages to mensuration of surfaces and solids and miscellanies. The tables in this volume consist of natural sines and tangents, ordinates, deflection distances, tangential distances, long chords, and board measure. The total number of pages is one hundred and thirty-four. The point that is now generally known as the point of intersection is termed by Mr. Griswold "the vertex." His definition of deflection angle corresponds with Mifflin's definition of the same. Forty-two pages of the book devoted to the art of leveling, mensuration and miscellanies will be found of little service in the field.

The first edition of the "Engineer's Field-Book," by C. S. Cross, was published in 1855. There are in this book twelve pages devoted to curve rules, fourteen pages to curve tables, and twelve pages to the prismoidal formula, with table. The total number of pages is forty-three. In this work the principal table consists of tangents for a one degree curve calculated for every minute from naught to ninety degrees. Most of the curve problems in this volume are solved by means of calculations for a one degree curve. There are about ten thousand tabulated computations in this little book. The second edition appeared in 1885. In addition to the aforesaid, this edition contains instructions to division and assistant engineers by Mr. Oliver W. Barnes. Also an article on Engineering Field Work by Mr. Chas. A. Smith, making an addition of about twenty pages. These last two articles, also the article on the application of the prismoidal formula, could be dispensed with in the field.

In 1855 Mr. Charles Haslett wrote a work entitled "The Engineer's Field-Book." The following is taken from the preface: "In presenting this work to the public the author claims for it the adaptation of a new principle in trigonometrical analysis of the formulæ generally used in field calculations. Experience has shown that versed sines and external secants as frequently enter into calculations on curves as sines and tangents, and by their use as illustrated in the examples given in this work. It is believed that many of the rules in general use are much simplified, and many calculations concerning curves and running lines made less intricate, and results obtained with more accuracy and far less trouble than by any methods laid down in works of this kind." This book contains one hundred and forty-one pages made up of thirty-two pages relative to curves, which treats of circular curves, compound curves and reverse curves. The remainder of the book contains tables of radii and their logarithms, natural and logarithmic versed sines and external secants, natural sines and tangents, table for curving railroad iron, &c. Very little of the information given in this volume can be classed as superfluous matter for a field-book, as it deals very directly with the field wants of the civil engineer. This book is now issued bound together with the same author's work on mechanics, thereby adding three hundred and seventy pages to the volume which do not pertain to field work.

The "Pocket-Book for Railroad Engineers," by O. Byrne, was written in 1855 also. It contains about one hundred and sixty pages, of which about eighty-five give rules for a great variety of curve problems. The remainder of the book treats of curve rulers, earthwork, cross sections, leveling, a table of ordinates and a table for earthwork. The following is an extract from the preface:

"All writers on this subject and compilers of pocket books for railroad practice, without exception, fill their works with tables too contracted for use, formulæ and rules too complex for practical men, or empiricisms that give results not sufficiently exact for practical purposes. It is well known that the simplest calculations cannot be made on the ground with any chance of accuracy, without retiring to a tent or house. The most the engineer can do is to store his field-book with topographical or instrumental notes, or with simple angular and linear measurements. Hence all helps to perform extensive calculations on the ground are useless." The method for laying out many of the example curves given in this volume is by means of offsets and chords. The most of them are solved by very elaborate algebraic demonstrations, some of which cover a whole page. This explains, perhaps, why Mr. Byrne preferred to use his field-book in the office.

The first edition of "The Field Engineer. Prepared with Special Reference to the Wants of the Young Engineer," by W. F. Shunk, appeared in 1879. Its contents is as follows: Explanation of the table of logarithms, occupying eight pages; plane trigonometry, ten pages; vertical curves, four pages; rules for curves and turnouts, seventy-eight pages; duties of field men, five pages explanation of the curve protractor, six pages; triangulating obstructions, four pages; together with the following tables: turnouts, radii and their logarithms; square and cube roots; loga-

rithms of numbers, sines and tangents; natural sines and tangents; chords, versed sines, external secants and tangents for a one degree curve, calculated for each alternate minute from naught to ninety degrees, various grades for a mile, &c., closing the work with six pages of advertisements, making a total number of pages three hundred and thirty-six. In article eighteen, Mr. Shunk speaks of the distance between the point of intersection and the point of curve as the "tangent or apex distance;" from this Mr. Trautwine has adopted the term of apex distance in the latest editions of his field-book. In all other cases Mr. Shunk uses the word tangent for what is now generally known as the tangent.

The tangential angle in this book is defined as by Mifflin and the deflection angle as by Trautwine. "The author's principal aim in preparing this volume has been, as its title indicates, to serve that large class of young engineers who, like himself, have not had the advantages of a technical education."

In 1880 the first edition of the "Field Engineering, Designed for Classroom, Field and Office," by W. H. Searles, was published. This book contains five hundred and seventeen pages devoted to the following: Reconnaissance, seven pages; preliminary survey, sixteen pages; theory of maximum economy of grades on curves, sixteen pages; location, three pages; simple curves, sixty pages; compound curves, forty-six pages; turnouts, thirty-four pages; leveling, sixteen pages; construction, thirty pages; calculation of earthwork, twenty-three pages; topographical sketching, three pages; adjustment of instruments, three pages; explanation of tables, fourteen pages. Also the following tables: Geometrical propositions, trigonometrical formulæ, radii, logarithms, offsets, etc., tangents and externals to a one degree curve, calculated from naught to one hundred and twenty degrees, long chords, middle ordinates, linear deflections, valvoid arcs, turnouts, middle ordinates for curving rail, elevation of outer rail on curves, various grades for a mile, table for obtaining barometric heights, correction for earth's curvature, and relative coefficient for reducing inclined stadia, lengths of circular arcs, minutes in decimals of a degree, inches in decimals of a foot, square and cube roots; logarithms of numbers, sines, tangents, versed sines, and external secants; natural sines, tangents, versed sines, and external secants excavation table, useful formulæ, closing with an appendix of two pages. The terms used in this volume are the same as used by Mifflin and Henck, except the point of intersection, according to Henck, is here known as the vertex, and the introduction of the term of external distance, which Henck in 1882 calls the shortest distance, both meaning the actual external secant.

This book is the most extensive and complete publication on field-work in the English language, and is, therefore, the best for the student. For field use about one hundred and sixty pages could be dispensed with without reducing its merit as a field-book.

The first edition of the "Pocket-Book of Tables and Formulæ for Railroad Engineers," by B. H. Hardaway, appeared in 1886. The following is the contents, printed on about fifty pages: Tables of trigonometrical formulæ; leveling by barometer, with table; calculation on earthwork, grades and grade angles, with table; coefficient for reducing

PRATTVILLE SEWERS
CHELSEA MASS.
SHOWING POSITION OF
FLUSH TANKS
AND
HOUSES
ENTERING SEWERS
NOV. 1886

W.E.M^CCLINTOCK.
CITY ENGR.

CIRCLES ARE MANHOLES ○
SQUARES " FLUSH TANKS □
HOUSE DRAINS ENTERED ▨
" ROOFS " ▩



inclined stadia readings to horizontal ones, with table ; radii, ordinates, offsets, and ordinates for curving rails, calculated for each thirty minutes of curvature from naught to twenty degrees ; elevation of outer rail, with table ; turnouts, with table ; table of curve formulæ ; article on transition curves, ending with tables of natural sines and tangents. This little book is intended to be used separately or together with a transit book manufactured especially for that purpose, the cover of the transit book having a pocket into which one of the covers of the field-book is inserted and thereby held inside the transit book.

Summarily, in regard to the terms which are considerably at variance in this branch of civil engineering, the same may be said to some extent to apply to the whole profession. The only way, perhaps, to remedy this evil is by a convention of civil engineers, to arrange a vocabulary of technical terms which should be adopted.

The most popular field-books that are now in use are largely made up of information that must necessarily be learned before taking charge of field work, or that apply to field notes after the field work is done. Nearly all of these books are intended for young men who have yet to learn the use of the level. The young man who has not advanced beyond this point in his profession has no use for a field-book. Therefore it is believed that the articles on leveling, cross sectioning, earthwork, reconnoissance, etc., occupy space which could be put to better use.

Many of the authors of field-books write with a view to supply both the young and the old engineers, and many wish to supply both the field and the college. These combinations always tend to lessen the standard of the work. The one must suffer from want of detail or the other must necessarily be overburdened with detail and matter foreign to field work.

The principal cause of the attempt to make so broad a scope with the field-book is the lack of a good text book, which, at the present writing, the profession is without.

CONSTRUCTION AND VENTILATION OF SMALL PIPE-SEWERS.

BY WILLIAM E. MCCLINTOCK, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 16, 1888.]

My paper to-night will more especially treat of a small system of pipe sewers that I constructed for the City of Chelsea, in 1883, the way they have worked, with some experiments on ventilation of small pipe-sewers made on this system in 1886.

The system, as constructed, consists of a wood box 186 feet long, across soft marsh bottom, 1,135.3 feet of 15-inch pipe, 1,635.6 feet of 12-inch pipe, 439.5 feet of 10-inch pipe, 1,776.8 feet of 8-inch pipe, 5,933.2 of 6-inch pipe. A total of 11,106 feet.

Manholes are built at each change in the line or grade and at intervening points for the purpose of ventilation and to give easy access to all parts of the sewers for inspection. There are 48 manholes in all, each having a cover with 37 one-inch holes through it for ventilation of the

sewers. The sewer passes through the bottom of the manholes in a half section of the same size as the sewer at its inlet and outlet. All changes in direction or grade are made in the manhole by a short curve, leaving a clear view from manhole to manhole. "Y" branches are placed on each side of the pipes at intervals of 25 feet, with the ends stoppered. Where the depth exceeds 15 feet, 6-inch chimneys are carried up to within about 9 or 10 feet of the surface, with a "Y" branch at the top, so that each side may enter, one at the top and one at the "Y."

The minimum grade is 0.25 foot to the 100 feet; the maximum grade is 15.80 feet to the 100 feet; the average grade is 3.94 feet to the 100 feet.

Seven Field's flush tanks were placed at the dead ends, having a capacity of 150 gallons each. The flush tanks are placed in the sidewalk and are connected into a Y branch about 10 feet from the extreme end, as in all cases the sewer ends in a manhole. All house connections are 4 inch, with traps outside the house.

At the outlet a brick tank is placed, 15 feet long, 6 feet wide and 7 feet deep below the inlet pipe, having an opening 6 feet square at the top, for cleaning out, with a brick arch over the rest of the top. Across the middle of this tank is a stop plank made of 4-inch matched spruce plank, with the bottom 18 inches below the invert of the inlet pipe and the top about the same distance above the top of the pipe. The space between the stop plank and the outlet pipe (6 feet square) is covered by a wire screen of half-inch mesh placed 3 inches below the invert of the outlet pipe and in a horizontal position. On this screen is placed a layer of coarse rye straw 3 inches in thickness, with a coarse wire screen on top to keep the straw in position.

By this arrangement all the lighter matters like paper, bits of wood or cloth and grease are held on the surface of the water above the stop plank, while the heavier substances settle to the bottom and the water that passes off is fairly free from any substance that is repulsive to the eye. In practice the effluent water is but slightly turbid and has but very little odor. The outlet is in a salt creek where the tide covers the marsh grass from two to four times each month, so that any finely divided matter that may be in suspension in the water is filtered out by the grass, and 200 feet from the outlet of the sewer there is no visible sign of sewage matter.

The tank is cleaned out once each month by the man owning the adjoining land, who composts the sewage matter for his farm. No perceptible odor comes from the tank even while it is being cleaned out; ordinarily, when the cover is removed, the smell is barely appreciable when standing directly over the tank. What becomes of the gases I cannot say unless they are held under the thick coating of matter that almost always rests on the surface of the water in the tank.

The building of the sewers was by contract, the city furnishing the pipe. Grades were given every 25 feet by driving spikes in the street on a 3-foot offset from the centre line and leveling on these and working out the cut in each case. Planks were then placed across the trench and uprights of 3 × 1 inch stuff nailed to the planks, and the cut in even feet marked on these. A line was then stretched from stake to stake on a parallel grade with the sewer and at the most convenient distance above

it. A grade pole, marked off into feet, having a strong iron shoe on it, with a piece extending out sufficiently far to lay into the end of the pipe, and stiff enough to lift the pipe at one end, while laying, if necessary, was used, and the grade of each length of pipe was given. The alignment of the pipe was kept good by plumbing down from the line. The pipes were laid as closely to an absolutely straight line as was possible. As a proof of what success we had in this direction, a stretch of 6 inch pipe, 900 feet long, could be looked through by using mirrors, the pipe being laid for that distance on an uniform line and grade. After the work was completed the sewer between each manhole was carefully examined and all foreign matter removed. Several brickbats and two half-round cleaning-pieces, fastened to a 3-foot stick, were among the things removed.

The cost of the work was as follows :

Tank.....	\$327.00	Inspection.....	\$756.75
48 manholes.....	2,506.63	Printing.....	49.10
Pipe.....	3,149.77	Sundries.....	329.74
Trenching.....	7,461.04	Flushing.....	750.72
Cleaning up.....	693.25		
" Ys".....	355.75	Total.....	\$16,679.43

I do not know as it would have any particular bearing on any other work to go into more particulars as to the cost. In order to get an outlet we had to excavate to a depth of about 23 feet for some distance on one line. Along this section the 6-inch chimneys were placed.

It would not be fair from the figures given, to say that \$8,000 per mile is the cost of a small pipe system, as the outlet and tank, and in fact the most expensive part of the whole district, is completed, while there yet remains 14,800 feet of small pipes, with no specials, to lay in order to complete the district, at an estimated cost of \$18,968. If we add this to the actual amount expended to date, it would give us \$35,647.75 as the cost of 26,800 feet, or 5.075 miles, or about \$7,000 per mile.

According to an estimate made by myself at the time the subject was before me, the same section would cost for combined sewers the sum of \$109,000. I will explain that part of this increased cost rises from the fact that if the street water was introduced the outlet would have to be carried 4,000 feet farther out, or to a point below a tidal dam, as the introduction of storm water, in connection with house refuse, into a water power privilege, would doubtless give rise to litigation, whereas, by keeping out the sand and gravel that comes with surface waters and by screening out the solid matter from the sewage, no obstruction is carried into the pond. As an offset in the other direction, there will have to be constructed at some time in the future a few storm-water sewers at an estimated total cost of \$4,000, which, added to the above estimated cost of the pipes, gives us a total cost for the separate system after both lines are completed, \$39,647, or an average of \$7,812 per mile. Taking the combined system as per estimate, the average cost per mile is \$21,477, or about three times the cost of the separate system.

To compare the above estimate with what it has cost in the rest of the city to build the combined sewers already in, we find that there have been constructed 26.69 miles of sewers of all sizes, from 12-inch pipe to 6-foot brick, at a total cost of \$400,000, or an average of \$15,000 per mile.

This will give a fair average of the completed combined system in Chelsea, as by far the greater part of the city is sewered.

From the above figures it will be seen that the combined system, as actually constructed, will cost from two to three times the separate.

I have no figures to show the cost of repairs of the combined sewers except for a few years back, as no detailed account was kept previous to 1880. Since 1880 there has been expended for repairs and cleaning the sum of \$2,500 on all the sewers exclusive of the section under consideration. On this section there have been expended \$500; \$400 of this amount have been used for cleaning out the settling tank, leaving \$100 for the regular repairs and cleaning.

I place no particular value on these figures, as with the small pipes we keep the outlet clean, while in the combined sewers we allow the whole matter to flow where it will. In the one matter of cleaning there is no doubt in my mind that the small pipes can be kept clean by flushing at intervals that must be determined by the particular conditions presented. We have had but two stoppages in four and a half years. These were removed at an expense of about \$5. One of the stoppages was caused by three bricks falling into a manhole and stopping in the outlet of a 6-inch pipe. The obstruction was easily located from one manhole and removed by the rods and hoe. The other was caused by an accumulation of grease in a dead end that was removed by the rods and hoe.

The only other cleaning required was the removal of sand from the manholes, as no catch pans have as yet been put in. The sewers are today almost as clean as when put in nearly five years ago. From experiments made by myself in 1886, it takes the water from a discharge of flush tank No. 1, located at the extreme end of Washington avenue, 40 minutes to reach the outlet, a distance of 4,900 feet. It is safe to say that everything passes out of every part of the whole system inside of an hour from the time it is placed there, leaving no chance for the generation of gases inside the sewer. There are no appreciable odors even standing over the manholes. In the course of some experiments on the ventilation I have spent hours in the manholes with no ill effect and hardly any discomfort as far as odor was concerned.

From the experiments on ventilation I will now attempt to give a few notes: The experiments were made to show the direction and force of any air current through the sewers, and the effect of discharging a large body of water quickly into a small pipe. Also to show the action of an air pressure caused by the air passing into a sewer at a certain velocity, and whether said current would be able to break the seal of any trap on a branch sewer.

The small map shows the system of sewers as built, and reference to it will show the location of the different manholes and flush tanks which are referred to in the following ventilation experiments.

The velocity of the air was measured by a meter capable of indicating one foot per second. The meter was held in the end of the sewer in such a way as not to decrease the section of the pipe, and yet so as to get the full influence of any movement of air that was passing through the pipe. The trials were made with the manhole cover off and then with it put on. The temperature of the air and sewer was taken, with the direction

and force of the wind. The depth of the manhole where the trial was carried on is given, with the gradient to the next higher manhole.

First Trial.—Manhole A at Eustis street 6-inch inlet, with flush tank No. 1 at the end of 8-inch connection running continuously and discharging as often as full.

Wind westerly, 3,692 feet per second; temperature of air, $48\frac{1}{2}$; temperature of sewer, $53\frac{1}{2}$; manhole 10 feet deep; 8-inch pipe coming in from Washington avenue; 6-inch pipe from Eustis street.

The trial began at 11:08:18 A. M. and continued till 11:51 A. M., a period of 42 minutes and 42 seconds. During this time the air traveled a total distance of about 1,500 feet. The velocity was fairly regular and the direction against the flow of water. The air was flowing at the time the trial was stopped. There were four periods of rest of the air: 1st, 45 sec.; 2d, 9 min.; 3d, 45 sec.; 4th, $1\frac{1}{2}$ min.

Before beginning the above trials the air in the 8-inch inlet of same manhole was tried but its velocity was not sufficient to move the meter. From time to time during the trials a lighted match was held in the 6-inch pipe at different points but at no time did it show the least regular movement in either direction. Particular care was taken to see if the extra flow of water at the time of a flush had any influence on the flow of air, but none was noticeable.

Second Trial.—November 16, 1886. Manhole A, at 8-inch inlet, cover of manhole off; temperature of air 42; temperature of sewer 52.

The trial lasted from 4:36 P. M. to 4:41 P. M., a period of 5 minutes.

The total distance passed over in five minutes was 250 feet; the rate of flow was very regular and against the flow of water.

Third Trial.—Same date and immediately following trial No. 2.

The meter was held for four minutes in the 8-inch outlet of manhole A, and failed to show any movement of air.

The result of the above trials was to show that the air flowed in the opposite direction from the water in the sewer; that the flow might be even and continuous for a long period of time up through the inlet of a manhole with no flow into the manhole from the outlet, showing that the air flowing up the sewer must be supplied through the manhole cover; that at different times the air will flow or will not flow through different inlets or outlets in the same manhole.

Fourth Trial.—November 10, at manhole D outlet. Wind southwest, light. Raining quite hard. Flush tank not running. For a few seconds there was a slight flow of air down the sewer from the manhole. For most of the time there was no perceptible movement of air. A lighted match held in the mouth of the sewer showed an occasional slight disturbance of the air. A lighted match held so as to just clear the water showed a slight movement of air with the water, but this did not extend a quarter inch above the surface of the water. The observations lasted 10 minutes, during which time the air in the manhole was very good, there being no perceptible smell.

Fifth Trial.—November 10, at Manhole D inlet, with the same conditions as in No. 4. A slight current of air was observed up the sewer from the manhole, lasting a few seconds. A lighted match held in the mouth of the sewer showed a slight movement of air back and forth, but not

enough to measure. A lighted match held very close to the water showed the same results as in the last trial. The sewage flowing through was about $\frac{1}{4}$ of an inch deep. The trial lasted about 10 minutes.

Sixth Trial.—Same day and same conditions as in the fourth trial. Manhole D outlet ; flush tank running.

There was one trial at the outlet and three at the inlet of this manhole made for the purpose of determining the effect of a flush on the air at a point 300 feet away, with a grade between the two points of .53 foot per 100 feet.

The first trial, at the outlet, showed no air moving before the trial began or after it closed. The air began to move in the direction of the water 35 seconds before the head of the flush water appeared at the manhole, and continued to flow for 5 seconds after. The total distance traveled by the air was 32 feet.

The second trial, at inlet, shows the air moving 1 minute 25 seconds ahead of the water and 25 seconds, after traveling 86 feet.

The third trial, at inlet, shows the air moving 1 minute 45 seconds ahead of the water and lasting 15 seconds after, traveling 63 feet.

The fourth trial shows the air moving 1 minute 32 seconds ahead of the water and lasting 5 seconds after.

The flow of air in the sewer when the flush tank was not running was hardly perceptible. At a point very close to the water there was a slight movement, but so slight as to be unmeasurable.

Seventh Trial.—At manhole E outlet, November 10, A. M.

Flush tank not running.

a, with manhole cover off, showed a steady flow for 6 minutes 10 seconds, equal to 800 feet, the air flowing against the water.

b, with the manhole cover on, showed a steady flow in the same direction for the same time, equal to 720 feet. The rate of flow after the first minute did not seem to be affected by the cover being on or off.

Eighth Trial.—Same conditions as in last. At inlet of manhole E. November 10, A. M.—This trial lasted 7 minutes, and indicated no flow for the first 2 minutes; 20 seconds; flow up of 97 feet in the next 3 minutes 40 seconds; flow down of 30 feet in the next 20 seconds; flow up of 14 feet in the next 40 seconds. The total flow up was 84 feet against the water, in the 7 minutes.

Ninth Trial.—Manhole E outlet, November 16, 300 feet from flush tank No. 1: Wind northeast, 3.98 feet per second; temperature in air, 42; in sewer, 52. Manhole cover off, to show the action of a flush.

The trial shows that the flush seems to exert no influence on the flow of air either at the inlet or outlet. The flow of air at two trials, one with the flush working, the other with it not running, was variable in quantity but at all times against the water.

Tenth Trial.—At manhole F, November 10, 1886, inlet = 150 feet from tank No. 1.

Flush tank working.

No movement of air was felt 20 seconds after the tank started to flow, and stopped when the water had about half passed the point of observation. The air flowed with the water for 60 seconds, and traveled 93 feet in that time.

A second trial at the same point showed the tank as starting at 0; air started in 20 seconds; water at point of observation in 53 seconds; maximum flow of water (by estimate) at 1 minute 15 seconds; air stopped 1 minute 25 seconds; air traveled 92 feet.

A third trial at the same point showed the tank as starting at 0; air started at 10 seconds; water at point of observation at 49 seconds; air stopped at 75 seconds. The air flowed with the water 98 feet.

Twentieth Trial.—Manhole F, inlet, wind northwest 3.98 feet per second; temperature air, 44; temperature of sewer, 52; tank not running; cover of manhole off.

The air flows in and out, but mostly out, against the water. In the first 11 minutes 20 seconds, the air traveled 384 feet. At this time the cover was taken off, when the velocity slackened up for 2 minutes, when it again moved as at first, passing over 472 feet in 14 minutes 40 seconds.

At the inlet we found that with the cover off there was a generally upward flow, when the air stopped moving, and at the end of $1\frac{1}{2}$ minutes started to flow down and continued to so flow during the rest of the trial, which lasted 9 minutes. The total flow up was 348 feet. The total flow down was 235 feet. The cover was put on the manhole 40 seconds before the upward flow stopped.

This manhole is 10 feet deep and on a grade of .5 per 100 feet, and is 150 from the extreme end of the line on this section.

The experiments seem to show that there is a flow one way or the other most of the time. That from the outlet it passes through the manhole and up the next section part of the time. That part of the time the air passes directly out of the manhole, and with the cover on draws from the next section, causing the air to flow down.

There is nothing to show that the air passed down from manhole E, with the water, except when driven for a few seconds before the flush water.

Eleventh Trial.—At manhole G, November 9.

There seemed to be a current of air either in or out of this manhole all the time except when the flush tank started up, when there was generally a short rest.

Twelfth Trial.—At manhole foot of Fremont Avenue, November 16, 1886, wind northwest, 3.83 feet per second; temperature air, 42 Fah.; temperature sewer, 52 Fah. No flush running. Cover of manhole on.

Trials were made at both outlet and inlet, and both showed a steady upward flow of air. The outlet trials lasted 7 minutes, and during that time the air flowed 500 feet. At the inlet the trials lasted 13 minutes, and during that time the air flowed 850 feet.

This makes the average rate of flow into the manhole 71 feet per minute, and up the inlet out of the manhole 65 feet per minute.

The grade of the sewer between this and the next manhole higher up the hill is 8.75 feet per 100 feet; the distance 360 feet.

Thirteenth Trial.—At manhole Fremont avenue and Laurel street, November 16, 1886; temperature air, 42 Fah.; temperature of sewer, 52 Fah.; wind northwest, 3.83 feet per second; cover of manhole off.

A trial for 5 minutes at the inlet showed the air to have traveled 440 feet, or at the rate of 88 feet per minute, the flow being very regular.

A trial of 8 minutes at the outlet showed the air to have traveled 386 feet, or at the rate of 46 feet per minute, showing that considerable more air passed up through the sewer from Fremont avenue to Laurel street than came into the manhole from the lower section sewer, the excess passing in at the manhole cover.

Fourteenth Trial.—At the manhole Laurel street and Garland street. Same day and same conditions.

A trial of 6 minutes showed the air to have traveled 450 feet, or at the rate of 75 feet per minute. This is the highest manhole in the section, in fact, the highest in the system.

Other experiments were made at different points but were not carried far enough to draw any conclusions from and are therefore omitted from this paper.

As a result of all my experiments I find that with a good grade there is always sufficient movement of the air to thoroughly ventilate the sewers many times each day. On the lighter lower sections the flow of air seems to be less active or constant, and as yet I am unable to state whether there is sufficient movement to ventilate to any extent. I find that the air passes in at some manholes and out at the next higher ones, ventilating the short section between the two.

The question that is now raised in my mind is whether by a careful study and actual trials the partial vacuum created in a sewer on a high level with a good grade can be made to extend its influence through the sewers to the lower levels where the normal action is very slight. If this is done, it may be done by placing close covers on certain manholes along the sewers to cause the air to be taken at a point nearer the outlet, while by intermediate close covers the outlet for the foul air will be placed at a higher level or even at the summit.

If this system can be made to work, the sewers will be thoroughly ventilated their entire length.

The possible objection to such a scheme might be that the foul air being concentrated at one point on the summit would tend to cause a nuisance at that point. At the same time if the ventilation could be effected, it might be an easy matter to take care of that part of the question. I think it a matter well worth the time and trouble to investigate more carefully and for a longer time.

Of course it follows as a matter of fact, that the oftener the air is changed the less foul it becomes, and the easier to handle, and if by a proper application of close and open covers, a current could be induced to flow nearly continuously through the sewers. I imagine we should hear but little complaint of the excess of foul air at any one point. As a matter of fact, I have been surprised at the remarkable freedom from foul odors in these small pipes, and at the clean condition after nearly five years use.

The experiments made on the air of these sewers are only a beginning of what should be carried out to give an intelligent idea of the flow of air through them. I for one have placed ventilated covers on my manholes because other engineers have said they ought to be there. At the present time I am far from satisfied that they should be placed at random along a line of sewers without knowing the effect they will have in the end.

DISCUSSION.

Mr. F. P. Stearns : I take it for granted that the time has passed for engineers to discuss whether the "separate" or the "combined" system of sewerage should be used exclusively ; and that we have reached the point when both systems are considered with reference to their applicability to the city or town to be sewered.

The separate system of sewerage was first applied in this country on a large scale but eight years ago in Memphis. Since the introduction of the system there, the number of systems built per year has increased until there are now in the United States a total of as many as 36, and they are being built more rapidly than ever.

Most of the features of a system of small sewers are simple enough to any engineer experienced in the construction of larger ones ; yet there are many details which must be based largely upon experience with the same kind of sewer to obtain the best results.

With a view of obtaining the latest information upon certain points from those having practical experience in the construction and operation of these systems, I caused a circular to be sent to those in charge at various places and have received many replies. It is my chief purpose, in taking part in this discussion, to present the substance of these replies, and of some others relating to the maximum rate of consumption of water during the extremely cold weather of last January.

The volume to be provided for in a small pipe system consists of domestic and other wastes, which may be called the sewage proper, and of ground water, with or without the addition of roof and flushing water. Where there are no overflows it is necessary to provide for the maximum combined flow from these different sources.

The sewage proper is in most cases about equal in volume to the water supply, and this reaches its maximum rate in this climate in severe cold weather.

The week ending the 28th of last January was extremely cold, and the consumption of water in several instances was reported to be higher than ever before known.

In answer to inquiries made at that time returns were received from which the following table has been deduced :

City or town.	Average daily consumption per inhabitant.	Maximum daily consumption per inhabitant in Jan., 1888.
Boston, Mass. (Cochituate and Mystic works).....	79	151
New Bedford, Mass.....	85	150
Brookline, Mass.....	71	100
Providence, R. I.....	39.5	54
Waltham, Mass.....	39	50
Newton, Mass.....	31.3	50
Taunton, Mass.....	31	43

These figures, giving the maximum daily consumption of water, show a very great diversity under what may be called somewhat similar conditions, and they show forcibly that a large allowance must be made in the capacity of the sewers to provide for the increased rate at which water is used on exceptional occasions.

The figures here given do not really give the greatest rate of water supply that has to be provided for, as the maximum rate of flow during

certain parts of the day is in excess of the average for the whole day, even during cold weather when so much is wasted at night.

In Boston, records are kept several times a day of pressures in the main at different points, from which it is easy to determine the losses of head between the distributing reservoirs and these points. From these data it was estimated that the consumption during several hours of the very cold weather, already mentioned, was at as high a rate as 170 gallons per inhabitant, or 2.1 times the average rate of consumption during the year.

Infiltration of ground water appears to take place when sewers are built through wet ground, even when great care is taken to prevent it. It is obvious that to exclude it wholly, not only the sewers and house connections must be tight, but no drainage of wet cellars can be permitted.

The replies received in answer to the question in the circular with reference to the infiltration of ground water are as follows:

Cedar Rapids, Ia.—“There is considerable ground water which has not been measured.”

Chelsea, Mass.—“Ground water about one inch deep in 15-inch outlet.”

Kalamazoo, Mich.—“Some ground water finds its way into the system, estimated from data taken before the sewers were open for public use to be 20 per cent. of the capacity of the mains.”

Norfolk, Va.—“No accurate estimate made, but ground water forms at least 60 per cent. of pumping.” From information given elsewhere in the returns the maximum flow is found to be about 167 gallons daily per inhabitant connected with the sewers. Of this the ground water, estimated at 60 per cent, equals 100 gallons.

Schenectady, N. Y.—“The sewers are laid through wet ground and quicksand in some instances. The Erie Canal seepage also affects them in a small degree. Measurements made at about the time the system was completed indicate that the infiltration of ground water amounts to about 5 per cent. of the capacity of the mains.”

This completes the information on this subject furnished by the replies. They indicate that where sewers are built through wet places the ground water is an important element.

Additional information on this point is furnished by the experience on the main drainage works of Boston. In February, 1887, at a time when no surface or storm water entered the sewers the daily flow by measurement in the reservoir was as high as 147 gallons per day for each of the 273,000 inhabitants then connected with this system of sewers. The average daily consumption of water in Boston per inhabitant during that month was 84 gallons; in the district connected with the sewers say 90 gallons, leaving 57 gallons to be accounted for by the infiltration of groundwater.

A portion of this, perhaps 12 gallons, is sea water, leaving 45 gallons, more or less, of fresh water.

To the question, “Do you exclude roof water?” seven answer “Yes,” five answer “No” while seven answer that roof water is mostly, but not wholly excluded from the sewers. Some of these admit it from public

buildings, others from private buildings at dead ends by special permit and it is also mentioned that, though theoretically excluded, some of it does find its way into the sewers.

The answers to the question, "Do you use 6-inch pipes for laterals and if so, do they operate successfully?" furnish the following information :

Nine use 6-inch pipes.

Two use 7-inch pipes.

Seven use 8-inch pipes.

One uses 10-inch pipes.

One uses 6 or 8-inch pipe, the choice depending upon the grade.

With regard to the operation of the 6-inch sewers, seven answers were received, in two of which it was stated without qualification that these sewers operated successfully, while the other answers qualified this statement. The opinions on this point can be better understood by quoting from the answers.

Cedar Rapids, Ia.—"We use 6-inch laterals on runs not exceeding 800 feet and grade of not less than 2 per cent."

Chelsea, Mass.—"Six-inch laterals operate successfully. We have as yet had no trouble of any kind. Minimum grade, 0.25 per cent."

Kalamazoo, Mich.—"They operate satisfactorily for residential portions under favorable conditions. Minimum grade, 0.48 per cent."

Keene, N. H.—"We have had no obstructions on our high grades except from roots, * * * but on our low grades we have an occasional stoppage, which can usually be removed by a stream from our hydrants."

Nahant, Mass.—"Six-inch laterals work well on grades varying from 0.5 to 2.0 per cent." Each house is provided with a large grease-trap, through which the waste from the kitchen sink passes on its way to the sewer.

Norfolk, Va.—All laterals begin with 6-inch pipe. On anything under 0.75 per cent. grade a flush tank is used at end of lateral. The general statement was made on the return that these sewers operated in a satisfactory manner, but that it is not entirely satisfactory may be judged by the following quotation from a letter received from Mr. W. T. Brooke, City Engineer, who suggests "that nothing less than an 8-inch pipe be used on laterals, for although theoretically the 6-inch may be all sufficient, yet from experience with the difficulties attending the misuse of house connections with the sewers, I am forced to regard 8-inch pipes as practically the best."

Wilkes-Barre, Pa.—"Grade 0.5 per cent. operating successfully; distance from flush tank to main sewer 500 feet. Would not advise the use of 6-inch laterals for greater distances or less grade than the above."

* * "I have discontinued the use of 6-inch laterals and use 8-inch instead."

Mr. Chas. N. Wood, City Engineer of Norwalk, Conn., writes that the sewers of this place are of the combined system, but that he has had some experience with 6-inch pipes, in separate systems of sewers, and believes that when the grades are 6 inches or more per 100 feet, and adequate flushing appurtenances are attached, they will work well as laterals. In another part of his letter he states: "I believe the separate

system to be *the* system, on account of cost, sanitary benefits, etc. Yet I think the tendency is to use too small pipes on light grades."

As the question asked did not refer to the operation of sewers larger than 6 inches in diameter, few answers were received concerning them, but all statements that were made were to the effect that they operated successfully.

I will quote two of the replies to the question: "Is there any special feature you would remedy in new work?"

Keene, N. H.—"On streets that have elm trees near the sewer would recommend that especial care be taken to make tight joints, so that roots cannot find their way into the pipe. We have been troubled very much on sandy soil with the pipe becoming filled with roots. The bottom of our pipe was not properly cemented, which allows the water in the pipe to leak into the ditch, thus attracting the roots, and several of our 6-inch lines have been badly obstructed."

Pawtucket, R. I.—"In the original design the water was carried upon the surface of the street too long. In constructing sewers for the last two years I have extended the sewers taking street water to greater lengths than shown on the original design."

In summing up the information received as to the different features of these systems it must be admitted that the weight of the evidence is rather in favor of the use of a sewer larger than 6 inches in diameter for the smallest size, particularly on light grades.

The lightest grade much used for laterals is about 0.5 per cent.

The maximum flow in sewers from which roof water is excluded will occur when the total volume due to domestic and other wastes, and to the infiltration of ground water is greatest. The wastes are greatest in this climate in extremely cold weather. The infiltration is probably greatest about the time the frost comes out of the ground. The consumption of water in the severe cold weather varies very much in different places with the habits of the people and the measures taken to restrict waste, consequently no definite amount can be stated which will apply to all places. In Boston it is at the rate of about 170 gallons per inhabitant per day.

The amount of infiltration of ground water is also a variable quantity, depending chiefly upon the length of sewer and house connections in wet ground, and upon the care taken to make them water-tight. The answers received indicate that the volume may be very large in some cases, and that no ordinary care will prevent a considerable quantity from finding its way into sewers laid in wet ground.

Whether or not roof water should be admitted to the sewers is not settled by the answers received; nor does it appear to me that it could be, as it must be settled by the local conditions and the cost. It is desirable as a sanitary measure to admit the roof water, and its admission will not generally make the cost excessive when the crude sewage is to be discharged into a stream of water not far distant. When, however, a long main sewer is required to carry the sewage to a suitable point of discharge, or when pumping or purification is required, the cost of dealing with the larger volume will frequently make it undesirable to admit it. For an approximate example of the increase of volume to be provided

for when roof water is admitted, assume that six persons live under a roof having an area of 1,000 square feet, that the maximum rate of flow of sewage and ground water equals 200 gallons per day per capita, and that one inch per hour of rainfall can be collected from the roof.

With these assumptions the flow of sewage and ground water would be at the rate of 1,200 gallons per day, and the flow of roof water at the rate of 15,000 gallons per day, a ratio of 1 to 12½.

In addition to names already mentioned, the following persons have furnished the bulk of the information herein quoted, and to them and to the others who so kindly answered my circular of inquiry I here desire to express my obligations :

Mr. Geo. S. Pierson, City Engineer, Kalamazoo, Mich., who also furnished information with reference to Schenectady, N. Y.

Mr. A. R. Sweet, Engineer and Superintendent of Sewers, Pawtucket, R. I.

Mr. W. B. Pierce, Borough Engineer, Stamford, Conn.

Mr. C. F. Ingham, City Engineer, Wilkes-Barre, Pa.

Mr. G. A. Mitchell, City Engineer, Cedar Rapids, Ia.

Mr. D. H. Sawyer, Superintendent of Sewers, Keene, N. H.

I also desire to acknowledge my indebtedness to Mr. Wm. M. Brown, Jr., of this city, who has taken a prominent part in the collection of the information.

Mr. F. Floyd Weld, City Engineer, Waterbury, Conn. (by letter):

Our practice here is to admit roof water, and rather encourage the arrangement of house connections to take it. The roof water is clean and acts as a good flush to the sewers when it rains, and if taken in the sewers does not run over sidewalks to freeze and make dangerous icy places, nor saturate the ground about houses, and run down outside cellar walls to make wet cellars.

In proportioning laterals I use the roof area, and in the case of outside residence streets which are not built up, I use an area which is the same as on some street fully built up, or which in all probability will have no more houses upon it. In the central or business portions the sewers are proportioned for a street closely built up to a depth of 100 feet from the street on each side; and allowance for one inch rainfall per hour is made. I use no laterals smaller than 8 inches diameter, and the house connection hubs or Y branches are all 6 inches diameter. In laying the house connection pipes, either 6-inch or 5-inch pipes are allowed (after the first pipe from the sewer), but nothing smaller than 5-inch can be used until the soil pipe inside the house is reached, where 4-inch is the smallest allowed. Our experience shows that a 5-inch pipe is the best size for the connection from an ordinary house. For large stores, hotels and some other large buildings we use 6-inch connections.

The lightest grade we have on an 8-inch lateral is 0.5 per cent., which is lighter than I would use if it were possible to get more grade.

I find that where an 8-inch lateral has a grade of less than 1.0 per cent. we have to give it special attention in the matter of flushing and cleaning. On the main sewers, which are of brick, we have grades as low as 0.1 per cent.

There are four flush tanks in use on 8-inch laterals. These give a good flush at the upper ends of the sewers, and would be used here in many places were it not for the objections of some of the city fathers to the cost of water to supply them. For flushing I depend principally upon a portable tank, arranged to deliver water from the under side into a tube leading down from the top of the manhole to the sewer pipe at the bottom of the manhole. This tank is an ordinary watering cart, such as is used in cities for sprinkling the streets, and the valve is opened by a lever on top of the cart. The flushing effect of a load of water discharged into the sewer in this way is excellent, far surpassing the flush from any automatic tank, on account of the larger quantity of water and greater head available.

The tube is made of galvanized iron, formed with a bend at bottom to fit into sewer pipe, and with iron braces at top to rest on manhole head. With this portable tank I can flush from one manhole to another and do not have to depend upon the flush from the extreme end only. My manholes are placed about 150 feet apart, the distance varying somewhat with grades and changes of direction.

We have never had a stoppage in a street sewer pipe, and I think the short intervals between manholes has helped to give us this freedom from stoppages by affording plenty of points for inspection and flushing.

We make the joints on pipe sewers with cement mortar only, and have used no special method for making water tight joints, except in the case of a cast-iron pipe sewer laid in the bed of a river, where I used rope yarn dipped in cement paste and calked into the joint.

I have made no comparisons of cost of double and single systems, although I have used both or either one as seemed best in each particular case, others questions than cost usually determining which to use.

Mr. George T. Nelles, City Engineer, Leavenworth, Kan. (by letter) :— I am now and always have been an advocate for the admission of roof water. My experience here has been that even with strict regulations to the contrary and close watching, that more or less roof water finds its way into the sewers from cistern overflows, yard slop sinks, and by direct connection with the sewers during storms. This being the case, and in view of the very small additional cost of the pipe necessary to carry the roof water, why is it not better to figure on the roof water from the beginning, and thus avoid future possibilities?

I have found some of our 7-inch sewers absolutely full during heavy storms without being able to locate the source. The continuous flushing during storms is an advantage that should not be underrated. Our city regulations specify 4-inch house connections. This is the source of over 90 per cent. of our trouble with the sewers. With sewers proportioned to carry the roof water a 6-inch house connection could be allowed, and in my opinion would be a great advantage. A 4-inch connection requires much more care on the part of the householder than most of them are willing to give the matter. Probably 95 per cent. of the complaints that come to this office of stoppages are due to this cause. Faulty construction has proved the most fruitful source of trouble here. Some of our early sewers are both out of line and grade. And notwithstanding

regular flushing there is a constant tendency to silt up in the low places. Our more recent sewers have all been built to a light, and none have been accepted unless the light could be plainly seen between all points on the same grade and line. The sewers so constructed have never given any trouble and are to-day perfectly clean and free from deposits. We rarely build laterals on less than a 1 per cent. grade.

Flushing tanks and manholes are essential to the successful operation of small pipe sewers. By the use of flushing shafts or lamp holes a certain percentage of manholes can be avoided on straight lines. But manholes should be placed at each change of grade or line. I have found the lamp holes a valuable help in the location of stoppages and the cleaning of silted sewers.

If called on to design a system of small pipe sewers I would, from my present experience, place the minimum size for laterals at 10 inches, and believe that in this way many of the troubles incident to the use of smaller pipe could be avoided at small additional cost.

Mr. W. B. Pierce, Borough Engineer, Stamford, Conn. (by letter): The separate system of sewers at Stamford is not fully constructed and only a portion is in operation, but a few notes may be interesting. The system was designed by Col. George E. Waring, Jr.

The borough is generally very flat, requiring the use of light grades, the minimum being those given by Baldwin Latham in his "Sanitary Engineering" for a velocity of 2 feet per second when running half full (see American edition, page 11).

The estimated length of each size of pipe in the system is as follows:

	Lineal feet.	Per cent.
6 inch.....	44,878	63.55
8 inch.....	11,354	16.08
10 inch.....	8,137	11.52
12 inch.....	2,077	2.94
15 inch.....	3,160	4.47
18 inch.....	1,015	1.44
<hr/>		
70,621 = 13.375 miles.		100

No roof water is admitted, all flushing being done by the use of Field's flush tanks, of which 72 have been provided, three being of 1,000 gallons and 69 of 150 gallons capacity. There are 31 manholes on the system, those on all pipes of less than 12 inches diameter being merely for access to hand-holes, the sewer pipe being carried through the manhole.

The main feature of the system is the disposal of the sewage, which is delivered by the main sewers into a well on Canal street and is then pumped into deep water in Long Island Sound.

The well is 8 feet in diameter, with 12 inches ring and 20 feet deep, the bottom being about 15 feet below mean high water. While building it, constant pumping of some 1,200 gallons per minute was required. It is plastered with neat Portland cement, and no leaks have been discovered since its completion. Three pumps, with a capacity of 300 gallons each per minute, have been provided—two of the pumps being intended for use in case of accidents or repairs. They are operated by three 4 horse-power "Otto" gas engines, and have been working fairly well,

The pumping main is 12 inches diameter and 7,200 feet in length ; 6,000 \pm feet of which is of salt-glazed vitrified pipe, and 1,200 \pm feet of cast iron. The main has given fair satisfaction, a few leaks only being noticed, although the head at times has been 20 feet. A stand-pipe is provided at the pump house. Six hundred feet of the iron pipe was laid under water, and here some difficulty was experienced, as the water was too deep to work in without a diver.

The method pursued was as follows: For a long distance the line runs across a mud flat, which is bare at low water. Here the 600 feet of pipe was laid on a small platform about 15 inches wide, to which it was lashed after the caulking was completed. When all was ready, oil barrels were attached to the raft, and at high water the pipe floated. It was then towed to place and moored, and as the tide fell off, the pipe grounded. The barrels were then removed and the operation was complete. The outer end rests on hard sand, which is not protected from washing by the effluent, but although the pumps have been in operation nearly 10 months there has been no perceptible wash.

The operation of laying the iron pipe seems very simple, but it required considerable good management to insure a success. A quiet day, with little or no wind, and even that off shore, was necessary. On the day of the first trial all the conditions were favorable, but with the ebb of the tide came a change of wind, which soon laid the pipe and barrels high and dry on the shore, broadside to.

A large part of the sewers, probably 75 per cent., was laid in very wet ground. The whole Borough, in fact, is underlaid with a water-bearing stratum of gravel, and in many cases continuous pumping was required. Especially was this the case in the district lying near the canal, a large portion of this section being originally salt meadow intersected with numerous small drains which caused much trouble.

On the line through John street, where 1,500 feet of pipe is laid, through this same gravel, 700 gallons per minute were often pumped. This pipe, which is now probably under 8 feet head, was laid with Stanford's Patent Joint and the leakage is trifling.

There is one feature of the work which may account for much of the leakage. With a view of protecting the sewers from possible breaks by plumbers and drain-layers, a 2-foot length of 4-inch pipe was inserted in each of the Y's. In some cases it has been found that the settling of the back filling has started the joints of these 4-inch pipes, causing small leaks. In dry soil this feature is a success, and in a gravity system these extra lengths should always be inserted ; but in wet soil, with a pumping system, it will not be well to use them.

Drain tiles were provided and used in the beginning of the work until it was found they would be approximately as large as the sewers, after which their use was discontinued.

A large portion of the system is now in use. The first house was connected November 23, 1887, and at present there are 70 houses connected, using the following fixtures :

Water closets.....	117	Slop hoppers.....	4
Bath tubs.....	135	Sinks.....	135
Wash bowls.....	98		
Wash tubs.....	58	Total.....	549
Urinals.....	2		

The house connections are all 4 inches diameter and through them the sewers are ventilated, no fresh air inlet being permitted on a soil pipe.

In addition to the house sewage system, there has also been constructed a "separate system" for the removal of storm water only. This system is about two miles in length, and ranges from 12 inches to 48 inches diameter. There are 8 manholes and a gravity outlet into the canal.

The cost of the entire system complete will be about \$125,000, of which about \$15,000 will be for superintendence, legal expense, land damages, etc.

Mr. A. R. Sweet, Superintendent of Sewers, Pawtucket, R. I.: While the admission or exclusion of rain water from roofs may be governed somewhat by soil and climate, I consider that it is advisable to provide sufficient capacity to the sewers for its care. In a town or city subject to the severe winters of our Northern States, the admission of roof water to sewers or special drains is imperative. It would in winter, owing to ice, be dangerous to life and limb to allow water from roofs of buildings to fall upon or run across sidewalks.

The available filtering or absorbing area of the ground in business portions of our towns and cities has been reduced so greatly by streets and buildings that it cannot care for roof water in addition to the water that naturally falls upon it. I do not believe that the admission of rain water to sewers can be entirely prevented. In Memphis, where probably greater efforts than in any other city in the United States have been made to prevent the admission of storm water, I found, upon inquiry, that the flow in the sewers was considerably increased during rain storms.

The maximum allowance of sewage per capita is estimated for Pawtucket at 10 cubic feet in twenty-four hours (that being the basis upon which the water-works were constructed) one half to flow off in eight hours.

In determining the size and length of laterals in the suburban part of the city, allowance is made for one inch of rainfall per hour falling upon 5,000 square feet of roof surface per 100 feet length of street or sewer.

The minimum size for lateral sewers in Pawtucket is 8 inches in diameter. I decided to recommend that size after considerable inquiry in other cities using smaller pipes. I found that 93 per cent. of all the stoppages reported in cities using small pipes were in 6-inch pipes, while but 4 per cent. were in 8-inch pipes. The system has been in use four years; we have had but one stoppage of a sewer and that was in a lamphole on an 8-inch pipe sewer, caused by an iron being dropped through a ventilating cover. I recommend for buildings used for residences 4-inch house connections and for business buildings 6-inch connections.

The minimum grade for pipe sewers, 8 to 10 inches in diameter, should be one in 200, and for mains, not less than 18 inches in diameter, one in 250.

I consider the flush tank the life of a small pipe system of sewers, for without it the system will be expensive, troublesome, and unless the greatest diligence is exercised it will surely fail. I had a good oppor-

tunity to test the value of flush tanks. In the year 1884 we had laid about three and one-half miles of small pipe sewers, about two-fifths being 8 inches in diameter. These sewers were in use without flush tanks from April and May, 1884, to June, 1885. In this short space of time (a little more than one year) they had become foul and ill-smelling. There was considerable of a deposit upon the bottom of the sewers, a thick vegetable growth upon the sides, and at manholes the inverts were one-half full of sand; in fact, the sewers were fast filling up. Flush tanks (thirteen in number) were put in operation in June, 1885. They, without any assistance, cleaned the sewers of sand and all deposits and have kept them in good condition.

In the year 1886 it cost the city of Pawtucket more to wash out two sewers without flush tanks (one built in 1876 and one in 1879), the combined length of which was about 2,000 feet, than any two miles of sewers in the city, and it is fair to say that they were clean but a few days at a time; while if there had been flush tanks they would have been clean all the time.

There are in use in the city of Pawtucket 23 Rogers Field flush tanks as improved in the year 1885 and patented in 1886. The water for these tanks is taken from the city water mains and costs the Sewer Department \$10 per year per tank. These tanks operate once in about fourteen hours. They have been in operation some of them nearly three years. We have not found one inoperative, neither has there been one cent laid out on them for repairs.

For ventilation of sewers as well as for inspection, I use manholes and lampholes with perforated covers.

Until such time as our plumbers become experts upon siphonage and ventilation, until cities and towns have complete control of the plumbing of buildings, and none but competent inspectors are employed, it will be more safe to ventilate sewers by openings in the centre of streets than through the soil pipes of buildings, as recommended by certain engineers.

The only city that I know of (Memphis) that built its sewerage system almost without manholes has, since the system was completed, built a number of them for inspection.

The sewerage system of Pawtucket is so designed that by the use of intercepting sewers the sewage is collected and discharged below the lower dam into tidewater, where, except for an hour at high tide and during low water in the Blackstone River, there is a strong outward flow. During storms exceeding one-fourth inch per hour the storm water and sewage is discharged direct through storm overflows into the river.

The sewerage system of Pawtucket, while partaking of many features of the separate system, is not a separate system as commonly known. The laterals are, as far as practicable, designed only for house wastes and roof water, the storm or surface water that falls on the streets being kept upon the surface until the main sewer is reached. Thence it is carried in the same channels as the sewage.

The ground water is collected and carried under the sewers to the storm overflows, or that was the plan. Two of our tile drains are now

stopped, and the water is forced into the sewer through the joints in the invert blocks.

I have found by experience in suburban districts (except in excessive showers, which occur but once or twice a year) that the storm water falling upon two to three thousand feet length of street surface and abutting areas, depending upon the grade of the street, can be allowed to flow in the street gutters without inconvenience to the traveling public or injury to the surfacing material of the street, and what little injury does then occur can be repaired for far less than the interest on the cost of increased dimensions of sewers and appurtenances.

The estimated cost of the sewerage system of Pawtucket complete, including the East District, is about \$16,500 per mile. Without the East District, the estimated cost is \$13,500 per mile. The cost of all sewers constructed to date, which includes all but about 3,000 feet of the brick sewers in this system, is about \$21,000 per mile. One sewer alone in the East District 3,200 feet in length cost \$36,000, it being through ledge.

The estimated cost of the sewerage system of the town of Lincoln, designed and partly constructed under my direction, is \$17,600 per mile. This system, although less than one-fourth the length, required the use of a greater percentage of brick sewers and large pipes than that of Pawtucket.

Mr. Geo. A. Kimball : In 1886, I designed and partially constructed a small pipe system of sewers for the City of Somerville. The system was designed for a territory of about 40 acres, the outlet being into the combined system, of which about 38 miles had been constructed.

The system was intended to receive roof water and a certain quantity of storm water, a portion of the storm water to be admitted through catch-basins provided with *small outlets*, the streets being graded in such a manner that the *surplus* storm water would continue down the street gutter to a water-course. Connection was also made with two old sewers, designed for sewage and storm water, by means of small pipes connected at the bottom in such a manner that the surplus storm water would continue in the old sewer to its outlet into a water course. The connections with the catch basins and old sewers were so arranged that the sizes were adjustable, allowing the admission of such amount of storm water as should be found best by practice. The largest pipe used was 12 inches and the smallest 8 inches. The minimum grade was 0.25 per cent. for the 12-inch pipe and 2 per cent. or more for the 8-inch.

Manholes were built at all changes in line or grade, and were about 300 feet apart. No flush tanks were constructed. The joints were made with cement mortar. The length of that portion of the system constructed was 4,564.2 feet, and cost \$5,723.93. About one-half the work was in deep cutting, the deepest being 20 feet.

The outlet was carried under a railroad and two water courses by a siphon of 8-inch cast-iron pipe 90.1 feet in length. The pipes have been flushed with water from hydrants carried through a fire hose into the manholes, from which the ball or "pill" is forced through all the pipes. Where the deposit is considerable, or consists of sand or other solid matter, the outlet at the manhole is plunged, the manhole and sewer above

is filled with water, and the sudden removal of the plug causes an 'effectual flush.

In answer to the points suggested in the circular signed by the secretary, I would say as follows :

1. Roof-water should be admitted unless the sewage is to be treated, or the outlet is unusually long.

2. Design for 70 gallons per day per capita, with a liberal allowance for storm or ground water, which will vary greatly in different localities.

3. Eight inch for short laterals and 6-inch for house connections.

4. In regard to grade, get all you can, not less than 1 per cent., but I have been forced to use 0.25 per cent., which requires frequent flushing.

5. Manholes should be built at all changes in grade or line; not, however, to be over 300 feet apart.

After twelve years' experience in charge of the maintenance of the sewers in Somerville, I am convinced that a pipe sewer laid with a 2 per cent. grade will require but little, if any, flushing.

This question presents itself. Cannot flush tanks be dispensed with on steep grades? They are expensive and in many places troublesome. It is possible that the financial return to the inventor is a partial explanation of their free use in some cities.

6. I have always used cement mortar for making joints.

7. Special features of construction should be adopted to suit the conditions. In places where the soil is sandy or the streets are unpaved, the sand will find its way into the sewers, and additional means for flushing should be provided, especially on flat grades. In wet or sandy soils unusual care must be used in making the joints tight.

8. Six thousand dollars per mile is a fair estimate of the cost for a small pipe system, while a combined system may cost twice or three times that amount.

On the general question of sewerage, although much in favor of the small-pipe system, I believe that engineers should use the system which best meets the particular case in hand, whether it is the "small-pipe system," the "combined system," or a part of each.

President FitzGerald: In the February number of the *Annales des Ponts et Chaussées*, 1888, Mr. Durand Claye, a leading French authority, reviews the Shone and Waring systems of drainage. The Shone system is dismissed with very few words, but the Waring system is examined with care and in detail. The article ends with the following *résumé*:

"Finally, we believe the Waring, as well as all other separate systems, is based on a sanitary error in assuming that rain-water, the washings of streets, etc., can be discharged into the nearest water-course without inconvenience. The running of water on the public streets is not permissible, without inundating the lower quarters of a city. The separate systems imply then a double system of sewers. On the contrary there is a necessity for constructing the sewers of a city in such a manner as to unite the dirty water from all sources, even including rain-water; excluding, however, heavy storms."

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JULY 10, 1888: President Whitelaw in the chair; twenty persons present when the meeting was called to order; the number was afterwards increased to thirty odd.

The minutes of the last meeting were read and approved.

As there was no business before the meeting, Mr. John Walker read his paper on "Cable Railways," which was discussed.

[Adjourned.]

JAMES RITCHIE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

JULY 28, 1888.—An excursion was taken to Leavenworth by twenty-seven Members, with thirty-six guests (including twenty-two ladies), and six guests of the Club., viz.:

Frank Allen and wife.
Kenneth Allen.
Dr. and Mrs. F. B. Tiffany.
D. Bontecou.
W. H. Breithaupt.
V. H. Hewes.
A. N. Connett.
John Donnelly and wife.
C. M. Duncan.
F. C. Florance.
J. Brown.
J. Walker.
J. H. Grove.
H. F. Hill.
W. D. Jenkins, wife and daughter.
H. W. Kerr and wife.
Wm. B. Knight and wife.
Miss Frye.

G. K. Musselman.
A. Potter.
Wm. Mendenhall.
Miss Olcott.
Miss Vreeland.
G. W. Pearsons, wife and two daughters.
E. J. Remillon.
J. Norris.
E. W. Stern and two ladies.
F. W. Tuttle and wife.
F. B. Tuttle and Miss Dodds.
M. N. Wells.
V. M. Witmer and Miss Reynolds.
C. E. Taylor and two Misses Danaker.
T. F. Wynne and wife.
F. Callahan.
Glen. Miller.
M. Hoffelt.
F. L. Miller.

GUESTS OF THE CLUB.

Gen. H. F. Devol.
S. H. Yonge.
T. C. Bradley.

F. Matthews.
Edwin Walters.
A. C. Stites.

Leaving the Wood Street Station of the K. C., W. & N. W. R'y by special train at 10 A. M., the party was first taken to the Soldiers' Home at Leavenworth, where they were met by Gov. A. J. Smith, of the Home, and his wife, Maj. W. B. Shockley, Adj. Gen. Robt. Hayes, Lt. Chas. Moore, Chief Surg. Dr. Weaver, Asst. Surg. Dr. McNary, and the engineer of the Home, Mr. Johns, and were joined by Mr. and Mrs. A. J. Tullock and Mr. and Mrs. Geo. T. Nelles, of Leavenworth. The dining hall was visited first, where 1,080 veterans marched in, seated themselves and began eating on the tap of the bell, to be followed by nearly as many more. The absolute cleanliness of the hall and kitchen was remarked with pleasure. On the

second floor was found a large hall with stage, seats and altar, to be used as theatre, ball room or church (Catholic or Protestant) as occasion requires. The ladies rested on a piazza in front commanding a fine view of the surrounding country while the gentlemen interested looked about the grounds.

Returning to the depot, the Leavenworth Rapid Transit Railway, through the kindness of Mr. Nelles, its Chief Engineer, carried the party by special train to the city, where an elaborate lunch was tendered at the Delmonico Hotel by Mr. Tullock, President of the Missouri Valley Bridge and Iron Works. Mr. Breithaupt proposed a vote of thanks to Mr. Tullock, which was unanimously accorded.

President Knight then called on Mayor Neely, of Leavenworth, who responded in a speech of welcome, and was followed by General Devol, who made a few remarks suitable to the time and place.

The new Union depot was opened for the occasion, and a serious delay avoided by the kind offer from the Union Pacific Railway of the use of their tracks to the fort.

Stopping at the shaft of the Leavenworth Coal Co., Superintendent J. E. Carr took the party over the works, and at the water-works the superintendent, Mr. Hastings, conducted them through the pump house and the electric light station near by.

At the fort carriages were in waiting to convey the ladies up the bluff. It being Saturday, there was no military display; but, as at the Soldiers' Home, excellent music was furnished by the band. Captain Knight, Department Engineer, with several other officers, met and entertained the party.

Returning to the station at about 6, a camera was in waiting to take views of the party, after which the train was taken back to Kansas City, arriving at about 9 o'clock, after a most enjoyable day.

KENNETH ALLEN,
Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

JULY 21, 1888:—A regular meeting was held at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Railway, at 7:30 P. M., Second Vice-President Beckler in the chair. There were present: Messrs. E. H. Beckler, Geo. O. Foss, W. W. de Lacy, Chas. W. Helmick, Walter S. Kelley, Hermann Kemna, A. B. Knight, J. S. Keerl, L. R. Lothrop, A. F. Whitcomb and Geo. F. Wickes.

The minutes of the previous meeting were read and approved.

The Secretary read a letter addressed to Gen. B. H. Greene, Chairman of Committee on National Public Works, from Hon. J. K. Toole, Delegate in Congress for Montana, acknowledging the receipt of the Memorial to Congress from this Society, praying for the re-organization of the National Public Works. He stated that the Memorial had been duly presented, and assures the Society of being entirely in sympathy with its object and purposes.

A communication from Mr. C. L. Strobel, Chairman of the Committee on Highway Bridges of the Western Society of Engineers, was read relative to the Report of that Committee, looking to "Bridge Reform," and containing a request for an expression of opinion by this Society upon the subject matter of said report, and asking answers to the following questions:

"1. Do you favor the appointment of a State Engineer?"

"2. Do you consider it desirable for bridge engineers to adopt a scale of minimum rates for preparing working plans and specifications for bridges?"

"3. Are you willing to co-operate with this Society by the appointment of a committee to consider and report on the subject of a scale of minimum rates?"

On motion of Mr. Foss, the Secretary was instructed to transmit the matter contained in said communication to each member of the Society, with the request

that they forward their views in time to be canvassed at the meeting of August 18th next, that the meeting may act in accord with the Society's opinion.

Mr. Foss, Chairman of the Committee on Topics, made a verbal report upon the progress of business in the hands of that Committee.

The question of the relative effective powers produced by a locomotive when pulling and backing was proposed and discussed at considerable length by Messrs. Beckler, Kelley, Knight and Wickes.

The Chairman recited a number of novel features introduced in laying track on the Montana Central Railway, and suggested the subject to the Committee on Topics as being probably a proper one for a paper assignment.

A general discussion followed upon the Wickes Tunnel, 6,170 feet long, in course of construction on the line of the Montana Central Railway, the completion of which is put down for the middle of September.

General discussions were entered into upon railroad trestles and upon the use of five rails on 16-degree and 18-degree curves on standard gauge.

Adjourned to meet at same time and place August 18, 1888.

J. S. KEERL, Secretary.

INDEX DEPARTMEN .

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

-
- Address, President's, Society of Engineers.** By Henry Robinson. Reviews engineering progress during the year. *Trans. Soc. Engrs.*, 1888, pp. 1-26.
- Batteries, Primary for Illuminating Purposes.** By Perry F. Nursey, before the Society of Engineers. Treats briefly the principles of the primary battery, outlines its history and then describes in chronological order the various batteries brought out. *Trans. Soc. Engrs.*, 1888, pp. 185-223.
- Boiler-Experiments and Fuel-Economy.** By J. Holliday, before the students' meeting Institution of Civil Engineers. Gives details of experiments made to increase the efficiency and economy of a certain boiler. *Proc. Inst. C. E.*, Vol. XCII., pp. 336-352.
- Boiler, Firmenich, Failure of a.** By C. F. White before the Engineers' Club of St. Louis. Gives results of examination as to the cause of explosion of a Firmenich boiler. *Jour. Assoc. Engin. Soc.*, Aug., 1888, Vol. VII., pp. 329-335.
- Boilers, Specifications for.** By C. G. Darrach before the Philadelphia Engineers' Club, Gives general specifications for boilers which requires the bidder to state not only the price for the entire work, including boiler, setting, fixtures, etc., but also the economy and capacity he will guarantee. Discussed. *Proc. Engrs. Club, Philadelphia*, Dec., 1887, Vol. VI., pp. 179-206.
- Brakes, Classification of Continuous Railroad.** By A. W. Metcalfe, before the Students Institution of Civil Engineers. Gives a classification of railroad brakes based upon the general principles of action. *Proc. Inst. C. E.*, Vol. XCII., pp. 315-335.
- Bridge Floors, Design, Strength and Cost.** By Edmund Olander, before the Society of Engineers. Gives a comparison of weight, strength and cost of various designs of bridge floors. Four plates. *Trans. Soc. Engrs.*, 1888, pp. 27-67.
- Bridge, Hackensack Draw.** Gives description of new draw-bridge recently built by the Erie Railroad over the Hackensack River, with drawings showing details of girders, turn-table, wedges and foundations of draw-span. *R. R. Gazette*, July 20, 1888.
- , *Harlem River.* A series of articles describing the erection of the Harlem River bridge, with details of contractors' plant, staging, etc. *Engin. and Build. Rec.*, July 14 *et seq.*, 1888.
- Canal. Waterway between Lake Michigan and Illinois River, by way of the Illinois River.** By R. E. McMath, before the Engineers' Club of St. Louis. Discusses the proposed waterway from a St. Louis point of view in respect to its physical, sanitary, economical and political consequences. *Jour. Assoc. Engin. Soc.*, August, 1888, Vol. VII., pp. 313-329.
- Canal Conference, Society of Arts.** At a conference recently held under the auspices of the Boston Society of Arts, fifteen papers on canals and inland navigation were presented. They cover the use, history, progress and present condition of canals, their influence on railroads, and a comparison of the costs of traffic on each. *Jour. Soc. Arts*, May 28 *et seq.*, 1888.

BOOKS.

- BAKER, B.** Long and Short Span Railway Bridges. Illus. \$2.00.
BOW, R. H. Economics of Construction in Relation to Framed Structures. 332 diagrams. \$2.00.
GROVER, J. W. Railway Bridges. 37 colored plates, folio, cloth. \$12.50.
GROVER, J. W. Iron and Timber Railway Superstructures. Illus. folio, cloth, \$17.00.
SPOONER, C. E. Narrow Gauge Railways. Plates, 8vo, cloth. \$6.00.
UNWIN, W. C. Testing of Materials of Construction. Illus. \$7.00.
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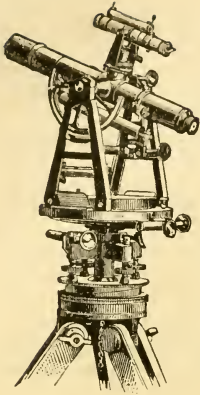
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- Canal Engineering.** By L. F. Vernon-Harcourt before the Society of Arts Canal Conference. Treats of the past, future aims and the prospects of canal engineering in the future. *Jour. Soc. Arts*, May 25, 1888.
- Canals and Inland Navigation National Works.** By Gen. Randall before the Society of Arts Canal Conference. Advocates the control of canals by the Government as national works. *Jour. Soc. Arts*, June 1, 1888.
- and *Railroads, Transport by.* By G. Lester before the Society of Arts Canal Conference. *Jour. Soc. Arts*, June 1, 1888.
- *Great Britain.* By M. B. Cotsworth before the Society of Arts Canal Conference. Gives the history, use and progress of canal and river navigation in England and Ireland. *Jour. Soc. Arts*, May 25, 1888.
- *Inland Navigation in Great Britain.* By E. J. Lloyd before the Society of Arts Canal Conference. Gives history of the development of inland navigation. *Jour. Soc. Arts*, May 25, 1888.
- *Inland Navigation, suggestions for its improvement.* By M. B. Cotsworth before the Society of Arts Canal Conference. Discusses the present condition of inland navigation in the United Kingdom and gives suggestions for its improvements. *Jour. Soc. Arts*, May 25, 1888.
- *Inland transportation in the 19th century.* By F. R. Conder before the Society of Arts Canal Conference. Discusses transportation in England by land and water, and shows how the canals have been taken in hand by the railroads at a loss. *Jour. Soc. Arts*, June 1, 1888.
- *Maintenance of.* By G. R. Jebb, before the Society of Arts Canal Conference. Discusses the work of a canal, method of maintaining them, with remarks on the special difficulties to be overcome in mining districts. *Jour. Soc. Arts*, May 25, 1888.
- Cement Tests.** By J. E. Codman before the Philadelphia Engineers' Club. Gives results of testing cement in different forms of briquettes. *Proc. Engs. Club*, Philadelphia, Dec., 1887, Vol. VI., pp. 168-172.
- Chimney Shafts, Stability of.** By R. J. Hutton before the Society of Engineers. Proposes to point out some errors which have crept into the theory of the stability of chimneys, and to offer some considerations as to the economical application of the theory in practical designing. *Trans. Soc. Engs.*, 1888, pp. 150-184.
- Combustion, Heat of.** By R. H. Buel. Treats of the heating powers of fuels as compared with that obtained from the results of chemical analysis. Gives tables of experiments on the heat of combustion of various compounds and coals. *R. R. Gazette*, July 27, 1888.
- Covered Way, Glasgow City and District Railroad.** By W. S. Wilson, before the Institution of Civil Engineers. Gives details of the construction of a covered way of which 2,600 yards were turned. *Proc. Inst. C. E.*, Vol. XCII., pp. 288-291; *Engin. & Build. Rec.*, June 23, 1888.
- Dams, Masonry, Profile of High.** By Isaac Morley. Derives a formula for determining the profiles of high masonry dams and discusses its application. *Engin. News*, Aug. 11, 1888.
- *Rock Fill.* An editorial discussing the use of rock fill dams. *Engin. News*, July 28, 1888.
- Earthwork, Formula for.** Gives a new formula, derived from the prismoidal formulas, for computing railroad earthwork. It also has a graphical representation. *Engin. News*, July 28, 1888.
- Economy of Structures, Comparison of the.** By Prof. G. S. Swain, before the New England Water-works Association. Discusses the proper method of comparing the economy of structures of different classes. *Jour. N. Eng. W.-works Assoc.*, March, 1888, Vol. II., pp. 31-34.
- Electric Balance, Thomson Composite.** By Thomas Gray. Full description of Sir Wm. Thomson's new balance, available as volt, ampere, or watt-meter. *Sci. Am. Supple.*, July 14, 1888.
- Electric Road in Hamburg.** By J. L. Huber, before the Institution of Civil Engineers. Gives details of the trial trips made on the Hamburg electric road with the Julien system. *Proc. Inst. C. E.*, Vol. XCII., pp. 304-311.



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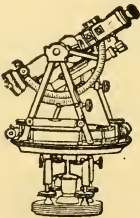
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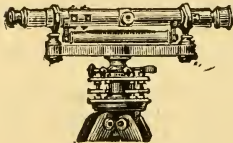


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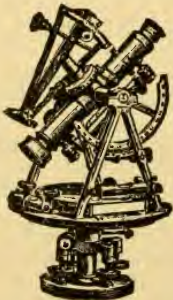
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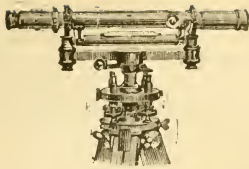
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INDEX DEPARTMENT.

- Electric Welding, Practical Application of.** By O. K. Stewart, before the Boston Electric Club. Discusses the present aspect of the question and tells what is now being done in practical work. *Sci. Am. Supple.*, July 21, 1888.
- Engine, Triple Expansion Non-Condensing.** Gives a description, with dimensions, of a triple expansion non-condensing engine that gave an indicated horse-power per hour for 1.45 lbs. of coal. *R. R. Gazette*, Aug. 3, 1888. *Engin. News*, Aug. 11, 1888.
- , *Triple Expansion.* Gives view and brief description of the triple-expansion engines of the steamer "City of New York." The cylinders are 45, 71 and 113 inches; stroke, 5 feet; indicated horse-power, 20,000 at 150 lbs. pressure. *Engineering*, Aug. 3, 1888.
- Engines, Copper Steam Pipes for.** By W. Parker. Before the Institution of Naval Architects. Gives a summary of investigations and results of experiments made to ascertain the behavior of different kinds of commercial copper under various treatments and temperatures. *Engineering*, August 3, 1888.
- Filtration, Practical Results of Mechanical.** By W. S. Richards. A paper before the American Water-Works' Association, giving experience with Hyatt filters at the Atlanta Water-Works. Abstracted *Engin. and Build. Rec.*, May, 1888.
- Flow of Water, New Formula for.** By E. C. Thrupp, before the Society of Engineers. Gives details of experiments with pipes and open channels, and show method of deriving his new formula for the flow of water. *Trans. Soc. Engrs.*, 1888, pp. 224-264.
- Gas, Water for Metallurgical Purposes.** By A. M. Wilson before the Iron and Steel Institute. Gives analyses of the various forms of water-gas; describes the plant most generally used for its manufacture, chemical reactions, etc. *Sci. Am. Supple.*, July 14, 1888.
- Heat and Power, Prall System of Distribution of.** By E. D. Meier before the Engineers' Club of St. Louis. Gives details of the Prall system of distributing heat and power from a central station as carried out in Boston. *Jour. Assoc. Engin. Soc.*, August, 1888, Vol. VII., pp. 305-313.
- Inland Navigation.** Fourteen papers on canals and inland navigation were presented before the recent Canal Conference under the auspices of the British Society of Arts. They are mostly indexed under canals. See *Jour. Soc. of Arts*, May 25, et seq., 1888.
- Lightning, Protection of Buildings from.** A lecture by Prof. Oliver J. Lodge before the Society of Arts. *Jour. Soc. Arts*, June 15, 1888.
- Mining Appliances in Westphalia.** By Messrs. Malkel, De Gournay and Suisse. Gives notes on the machinery, appliances, mode of working, etc., of the collieries of Westphalia. *Proc. Inst. C. E.*, Vol. XCII., pp. 367-376.
- Masonry, Proper Construction and Cost of.** By T. H. McKenzie, before the Connecticut Association of Civil Engineers and Surveyors. Gives specifications, with comments, for first-class masonry. *Proc. Conn. Assoc. C. E. & Surv.*, 1888, pp. 45-54.
- Plumbing, Specifications for.** Gives specification of the Board of Health for plumbing in New York City. *Engin. & Building. Rec.*, July 21, 1888.
- Railroad Construction from Preliminary to Track.** By M. P. Paret. A paper for young engineers, giving points on the ordinary methods and routine of field and office work on railroad construction. *Engin. News*, Aug. 11, 1888.
- *Location with Taper Curves.* By Frank Olmsted. Gives method of locating curves with tapering ends. *Engin. News*, July 21, 1888.
- Railroads. Ruling Gradient.** By E. Holbrook. Discusses how to determine the best gradient for a railroad. *Sci. Am. Supple.*, July 21, 1888; *R. R. Gazette*, July 27, 1888.
- *German Switch Movement.* Gives a translation of a lecture before the Berlin Railroad Club discussing the arrangements by which a close contact in split switch worked from a distance is obtained. *R. R. Gazette*, Aug. 10, 1888.



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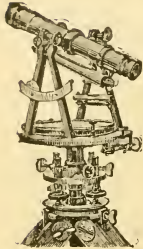
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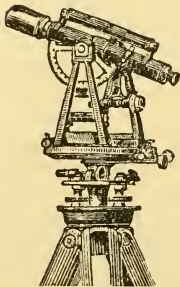
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- Rails, Steel.** By T. A. Delano. Gives brief discussion of some of the conditions of manufacture which may greatly influence the life of steel rails. *R. R. Gazette*, Aug. 10, 1888.
- Refrigerating Machines on Board Ship.** By T. B. Lightfoot. Gives early history of refrigerating machines and then describes in detail special machines for use on board of ships. *Trans. Soc. Engrs.*, 1888, pp. 105-124.
- River Gauging at Vyrnwy Reservoir.** By J. H. Parkin, before the Students Institution of Civil Engineers. Gives details of the gauging to determine the daily discharge of the Vyrnwy River. *Proc. Inst. C. E.*, Vol. XCII., pp. 353-367.
- Roof Truss, Renewal of at King's Cross Terminus, G. N. R.** By R. M. Bancroft before the Society of Engineers. Gives details of the renewal of the roof truss over the departure platform of King's Cross terminus of the Great Northern Railroad. Nine plates. *Trans. Soc. Engrs.*, 1888, pp. 125-145.
- Sewerage, Assessment of Costs of.** By T. W. Whitlock before the Connecticut Association of Civil Engineers and Surveyors. Discusses the proper method of assessing property for sewerage improvements. *Proc. Conn. Assoc. C. E. and Surv.*, 1888, pp. 57-62.
- , *Shane Hydro-Pneumatic System.* By Edwin Ault before the Society of Engineers. Gives full description of the Shane hydro-pneumatic system of sewerage, with details of the works at Eastborne, House of Parliament and Henley-on-Thames. *Trans. Soc. Engrs.*, 1888, pp. 68-105.
- Ship Railway, Venetian.** By E. L. Corthell before the Philadelphia Engineers' Club. Gives an interesting sketch of ship railroad project carried out in Venice in the 15th century. *Proc. Engrs. Club, Phila.*, Dec. 1887, vol. VI, pp. 153-165.
- Surveying, Plane Table.** By Josiah Pierce, before the Institution of Civil Engineers. Discusses the economic use of the plane table in topographical surveying, with discussion. *Proc. Inst. C. E.*, Vol. XCII., pp. 187-256.
- Timber, Dry Rot in.** By W. H. Bidlake. A report presented to the Science Standing Committee of the Royal Institute of British Architects. It is based upon 17 cases of dry rot. *R. I. B. A. Journal*, June 14, 1888; *Engin. and Build. Rec.*, July 14, 1888.
- Trestle Work, Special Features in Wooden.** Discusses the use of mortise and tenon-cap bolting, end bearings, etc. *Engin. News*, July 21, 1888.
- Tunnel, Alignment of Nepean, N. S. W.** By T. W. Keele before the Institution of Civil Engineers. Gives details of the alignment of the Nepean Tunnel for the Sidney water supply, New South Wales. Length of tunnel, 23,507 ft., $7\frac{1}{4}$ ft. high, and $9\frac{1}{2}$ ft. wide. Error in alignment for 4,341 ft. was $\frac{5}{8}$ in., and in levels, $\frac{1}{4}$ in. *Proc. Inst. C. E.*, Vol. XCII., pp. 259-267.
- , *Coosa Mountain.* Gives brief description, with section, of the tunnel on the Columbus & Western R. R., near Birmingham, Ala. Length, 2,434 ft.; width, 16 ft. with centre height of $21\frac{1}{2}$ ft. *R. R. Gazette*, Aug. 3, 1888.
- Water-Meters. Recent Tests at Boston.** By L. F. Ries, before the Boston Society of Civil Engineers. Gives details of the methods and apparatus used in "making a full test and report" upon the merits of water-meters for the Boston Water Board. *Jour. Assoc. Engrs. Soc.*, August, 1888, Vol. VII., pp. 285-297.
- , *System of Providence, R. I.* By E. B. Weston, before the Boston Society of Civil Engineers. Gives details of the management of the water-meter system at Providence, R. I., where 58 per cent. of the consumers have meters. *Jour. Asso. of Engrs. Soc.*, August, 1888, Vol. VII., pp. 297-304. *Engn. News*, Aug. 11, 1888.
- Water Pipes, Dimensions of.** By J. E. Codman, before the Philadelphia Engineers Club. Discusses the diameter of pipe flanges, diameter of bolt circle, size and number of bolts and thickness of cast-iron pipe. Gives diagram to show graphically the above points. *Proc. Engrs. Club, Phila.*, Dec., 1887, Vol. VI., pp. 150-152.
- Water Supply, Aeration of.** By S. E. Babcock, before the New England Water-Works Association. Describes the method of aeration adopted at Little Falls, N. Y. It consists of a series of mains constructed in an open paved channel. *Engin. and Build. Rec.*, Jan. 30, 1888; *Sci. Am. Suppl.*, July 14, 1888.

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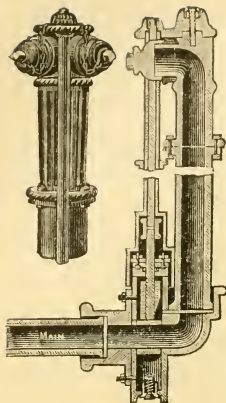
Water Supply, Biological Examination of a. By W. T. Sedgwick, before the New England Water-Works Association. Discusses the methods, results and their interpreting of biological examination of water. Discussion *N. Eng. W. Works Assoc.*, June, 1888, Vol. II., pp. 7-26.

—, *Charges for.* Discusses the charges for water by measure and assessment. *Engineering News*, July 28, 1888.

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Outlet.....	57.5	65.79	0.63	678.18
LUDLOW—(gate)				
Inlet.....	71.7	73.72		
Outlet.....	48.5	56.19	17.53	667.32
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Inlet.....	80.1	81.9		
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THE PLANT OF THE BOSTON HEATING COMPANY.

BY A. V. ABBOT, CHIEF ENGINEER OF THE NATIONAL SUPERHEATED WATER COMPANY, OF NEW YORK.

[Read before the Boston Society of Civil Engineers, November 16, 1887.]

A few days ago one of the local papers facetiously remarked that "the citizens had, during the past few months, a good chance to examine all the subsoil of the Boston streets, for within that time nearly every cubic inch of it had been frequently exposed to view." Now I am glad to have an opportunity of explaining to the scientific portion of Boston why some of this exposition of the subsoil has taken place, not with the view of mitigating any of the trouble or inconvenience that has been experienced, but to enable you to draw on your imaginations and to consider some of the advantages that will be derived in the future.

If Herbert Spencer had written upon the evolution of a city, I think that he would have remarked that the line of progress was from the individual to the corporation. In the small village each man has his cow, his well, his kerosene lamp and his wood pile; in the city we have milkmen, a gas company, the municipal water-works, and, we hope to have very soon a heating plant. Strangely, nearly every domestic want excepting that of heat has been already supplied in the larger cities from corporate institutions.

In a few places attempts have been made to introduce some means of delivering heat from a central station. Probably Pittsburgh, from the advantages derived from the almost inexhaustible supply of natural gas which there exists, has made a more widespread success in this direction than any other place. From the gas wells in the vicinity of that city an enormous supply of natural gas can readily be obtained at a pressure sufficient to force it many miles from its source, and to distribute it to all consumers. Obviously, very few places have such natural advantages, and some other means must be devised if it is desired to furnish heat in a location not supplied with gas wells. Several plants have been introduced to deliver heat by means of a number of boilers located at a central station supplying live steam to a series of pipes extending through the streets of the district to be served. The steam thus distributed may be used in any way in the same manner as if it was drawn directly from the boiler itself. Where plants of this kind have been carefully introduced with appropriate engineering skill, and with due precautions against the liabilities to which they are exposed, steam heating has been successful.

Recently another idea has been introduced which, it is believed, will obviate some of the difficulties which attend the use of steam for the distribution of heat on a large scale, and which will enable the necessary plant to be constructed much more cheaply. This system involves the circulation from the boilers of hot water, not of steam.

The object of the heating system is to distribute heat from place to place, and whatever means is used to carry heat from point to point is simply auxiliary, the distribution being the end to be accomplished.

Before we proceed further, we must establish some standard by means of which heat can be measured. If one is to measure milk, the quart is the unit; if land, the acre; if cloth, the yard; and so with heat, a unit is necessary. The unit that is adopted in this country is the quantity necessary to raise a pound of water one degree; strictly I should say that a unit of heat is the quantity of heat necessary to raise a pound of water from $38\frac{1}{2}$ degrees to $39\frac{1}{2}$ degrees, the point of maximum density.

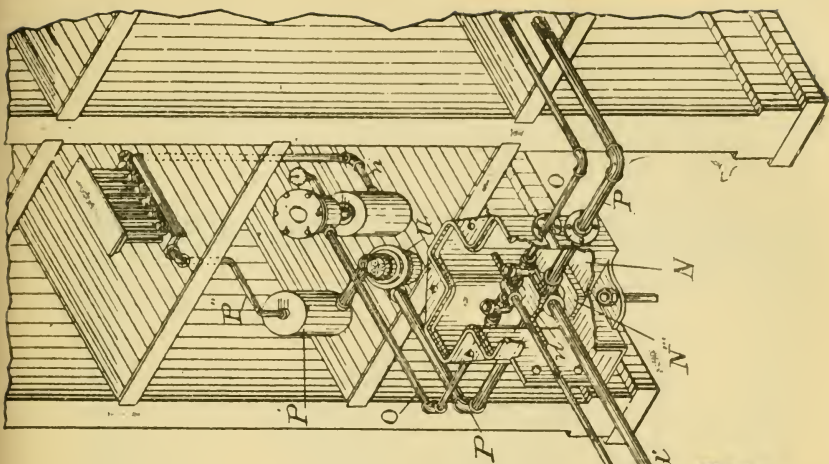
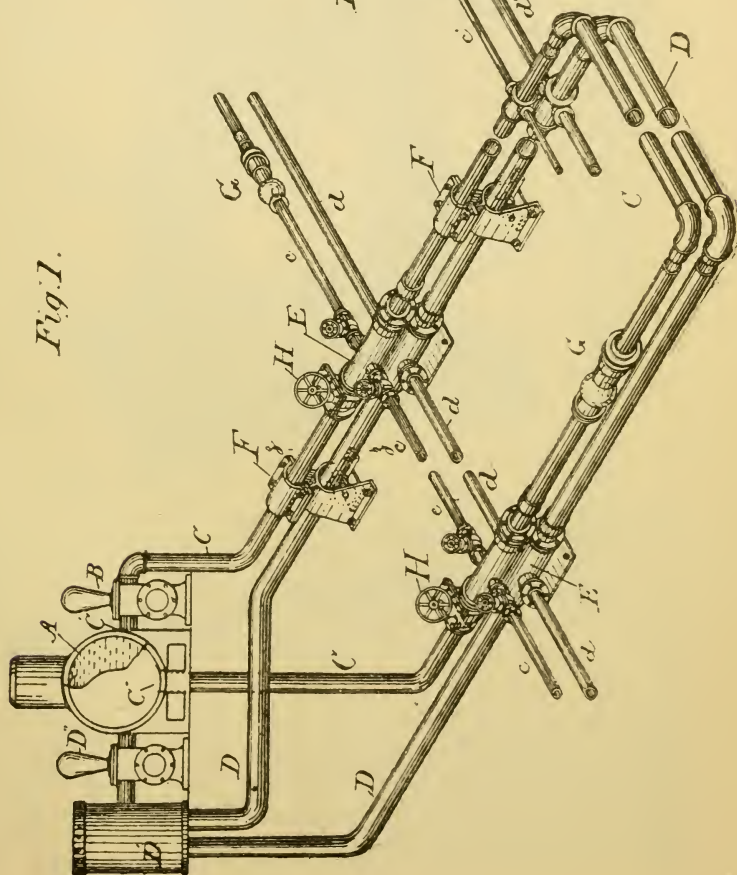
Water was selected as a measure for heat, because it was supposed to have the greatest capacity for heat of any known substance. Now a solution of sugar and element of bromine are found to have slightly greater specific heats. With the unit of heat we can express quantities in terms of that measure—for example, one thousand units of heat is the quantity necessary either to raise a pound of water one thousand degrees or one thousand pounds of water one degree. It is true that the specific heat of water increases slightly as the temperature rises, but that increase is so very small that for anything but the most accurate and exact calculations it may be neglected.

To carry any substance from one point to another we wish to select for our means of transportation that arrangement which will enable us to convey the greatest amount for the least expenditure. If we want to haul a thousand tons of earth, we get the largest cart that the horse can easily draw; if we wish to carry a load of rails, we obtain the largest car that can accommodate them. So, for the transportation of heat, we naturally select that substance which will convey the largest amount of heat. Mercury, oil, steam, hydrogen gas or petroleum could be employed; but, inasmuch as water, per unit of volume, will contain the most heat, it is obvious that it is best adapted as a vehicle. It would be possible for us to use a solution of bromine or sugar, to which I have alluded, but these substances have too slight an advantage in specific heat over that of water to render their use advisable.

Reference to the accompanying illustration, Fig. 1, may aid an understanding of our system. At a central station* a number of boilers are located, exemplified in the illustration at *A*. From the boiler *A* proceeds a pipe *C'* to a pump *B*. This pipe is attached to the suction end of the pump, and consequently the action of the pump withdraws the water from the boiler. Proceeding from the discharge end of the pump a pipe *C* extends through the streets, and returning to the central station, enters the boiler at *C''*. As soon as the pump is set in operation, the water flows out of the boiler by the suction pipe *C* and is forced around through the streets and back again into the boiler by the pump. If, during its passage, no water is taken from the main, every stroke of

*The plan of station is shown in Fig. 1a.

Fig. 1.



the pump withdraws from the boiler and returns to it again an equal quantity of water. In reality the office of the pump *B* is simply to sustain a continuous circulation through the hot water main.

Directly beneath the hot water main *C* there will be seen the pipe *D*, which in the station terminates in the tank *D'*. This second main collects the water as fast as it is used and cooled, and returns it to the sta-

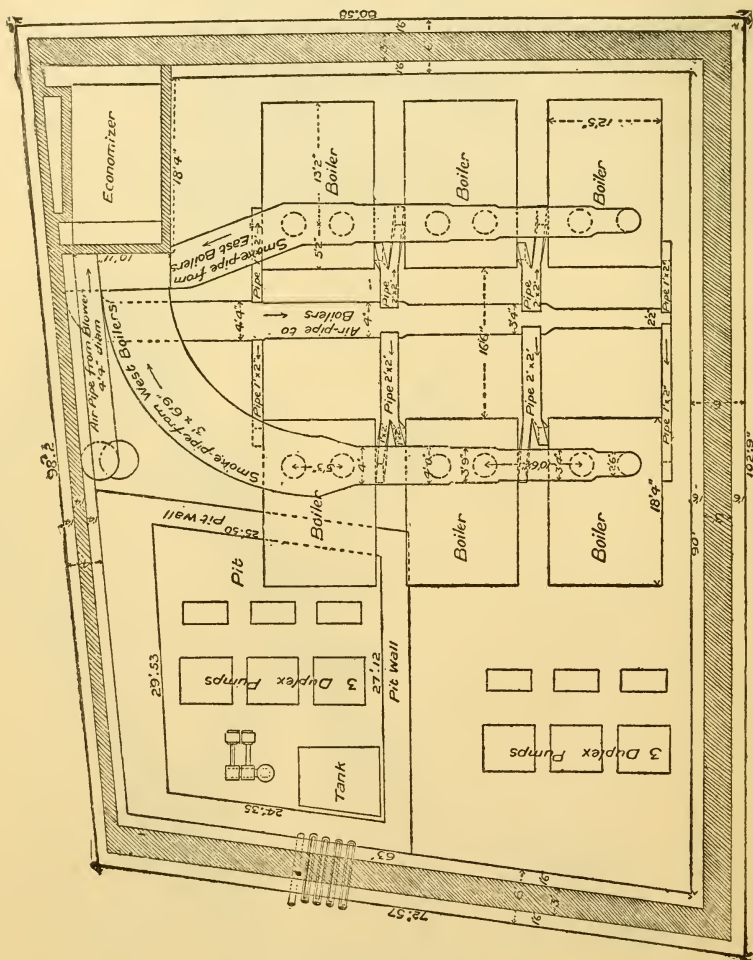


Fig. 1a.

tion, from which function it derives the name of the return main. As the return main empties into the tank *D'* all the water which is cooled and carried back to the station is delivered into this tank, from which a second pump *D''* draws the water and forces it back into the boiler, again to receive a fresh quantity of heat, and to be ready for another journey through the supply main.

From point to point along the supply main small pipes c' extend to the curbstone and terminate in the service box N . The pipe in the service box is so arranged as to enable a single box to supply three houses. This is accomplished by capping the end of the pipe with a three-way tee to which are attached three asbestos cocks. From this tee in the service box small copper pipes O extend into the adjacent houses furnishing them with a supply of hot water. Directly beneath the supply pipe c' is a similar, though larger pipe d' , to collect the cooled water from the houses and conduct it to the return main. This pipe d' also enters the service box; and there, by a similar arrangement of tees and cocks, is enabled to receive the water from the three buildings which the hot water pipe directly above supplies.

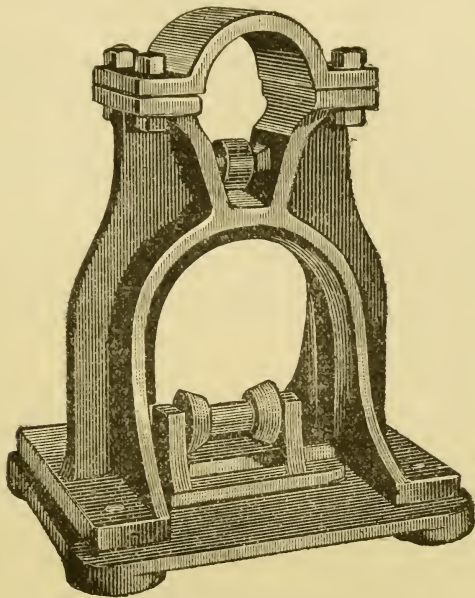


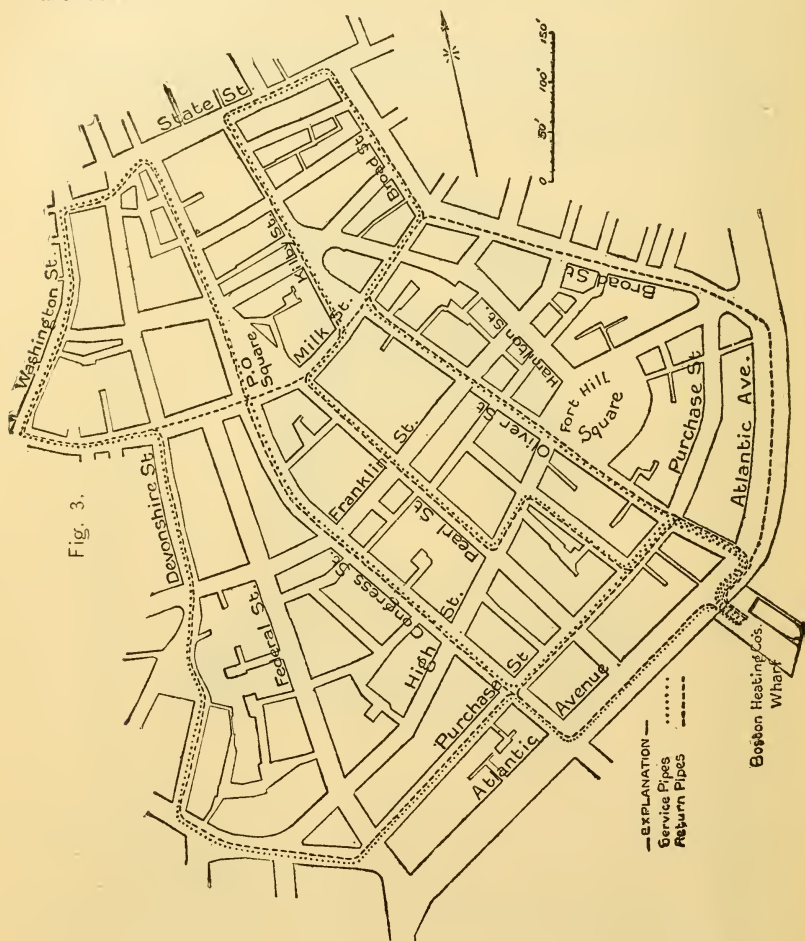
FIG. 2 BRACKET.

At the risk of being a little tautological, I will very briefly go over the circulation again, so as to emphasize the way in which the water passes out of the station, through the streets, and back into it again.

We have a boiler in the station—there may be a single boiler or there may be a large number, depending on the size of the district to be heated. From the boiler the water passes into the suction end of the pump; from the discharge end it runs through the street and back into the boiler again, maintaining a steady circulation for the purpose of keeping a constant temperature in the supply main. From various points on the supply main small pipes are laid, extending into the houses and stores, from which a quantity of water may be drawn off and used in any way.

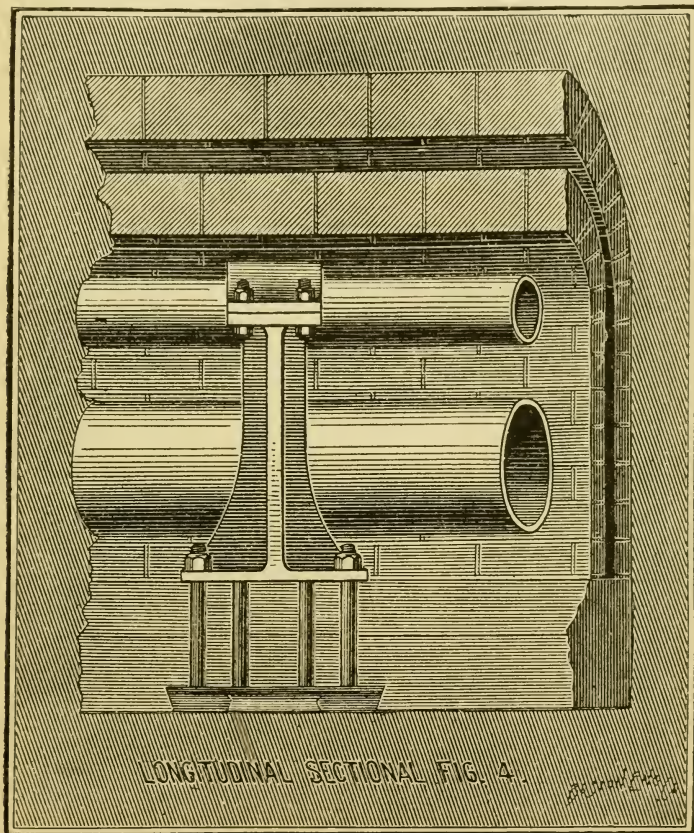
After the water is cooled it returns through a second pipe into a second main laid under the first, which returns the cooled water into a tank, from which tank a second pump forces the water back into the boiler again.

In the plant which we have introduced this season the return mains are all laid to grade, so as to conduct all the cooled water to the station by gravity. It is, however, possible to arrange the house appliances, which I shall describe in a few moments, so that they may be capable of returning the water to the station over a higher grade than that at which they are located.



Neglecting any slight leaks, unavoidable in so large a plant, and excluding waste that may occur from a thousand and one contingencies, the system, once filled, will always remain full, the water being simply the vehicle by means of which the heat received from the central station is transported to a distance. It is the car in which freight is carried, the water itself having nothing to do but act as a messenger, and after it has left its load of goods it returns to the station to receive another and repeat its journey.

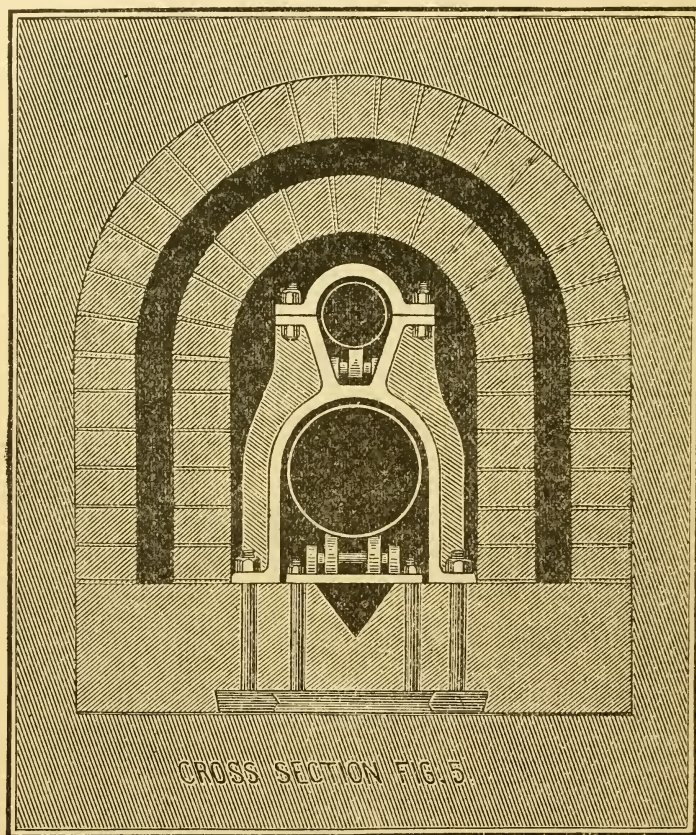
Those who have watched the work in the streets during the past three months have noticed that we have excavated a trench some $2\frac{1}{2}$ or 3 feet wide, and varying in depth from $2\frac{1}{2}$ to 7 or 8 feet, having an average depth of 4 feet. The trench has been excavated to grade between the street corners. Along the bottom of the trench we have spread a uniform layer of concrete 8 inches in thickness made of one part of cement, two parts sand, and two parts broken stone thoroughly rammed into place. Once in about 15 feet a brick pier has been introduced in the concrete and



solidly imbedded therein. On this brick pier has been placed an iron construction called a bracket, Fig. 2.

The bracket consists of a solid, arch-shaped casting supporting a roller covered by a cap. The office of this roller is to carry the four inch supply pipe and allow it sufficient ease of motion so that it may readily expand and contract under the variations in temperature; while the cap surmounting the whole confines the pipe sufficiently in its place so as to maintain it in a fairly straight line and prevent it from becoming in any way displaced. The whole bracket stands on top of the brick

pier, while directly underneath the arch of the bracket a second roller, placed on a small iron stand, is seen, the office of which is to support, in a similar manner, the eight-inch return pipe, and to permit of perfect freedom for expansion. It would seem that there was quite a disproportion between the supply and return pipes. The supply pumps at the station, taking their suction from the boiler, are able to maintain through the small supply pipe a rapid current. We expect to carry a



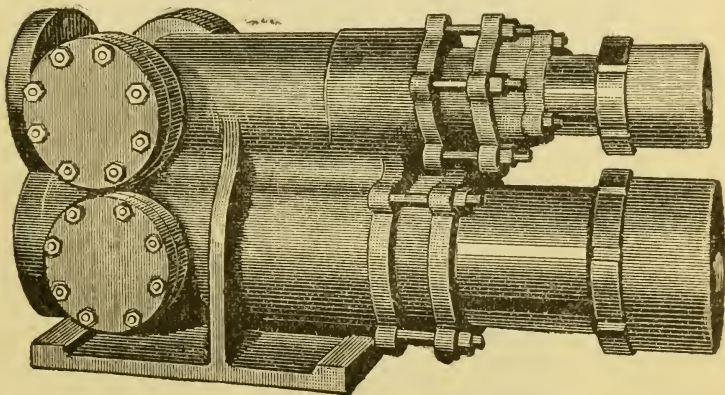
circulation, depending on the demand on the system, of from five to ten feet a second. By means of the pumps, this forced circulation is easily accomplished. While a small pipe for the supply pipe adds to the frictional resistance offered to the pumps, the radiating surface is largely diminished, the cost of the pipe is much decreased and the ease of construction is greatly facilitated. In the return pipe, when the water is to come back to the station by gravitation alone, it is necessary to decrease the frictional resistance as much as possible to afford an abundant chance for the water to run back easily and freely, no matter whether the discharge from the houses is regular or irregular. So we

have for the return pipe an eight-inch pipe and for the supply a four-inch.

The territory covered by our plant is shown on the map, Fig. 3, while the construction of the conduit is illustrated by the longitudinal section, Fig. 4, and transverse section, Fig. 5. In actual steam practice it is found absolutely essential wherever there occurs any change in direction of the pipe line, to introduce some means to provide for the expansion which is due to the variation between the temperature at which the pipe is laid, and that which it attains so soon as circulation takes place. Experiments on various mechanical contrivances have convinced us that the best joint to be used for our purpose is the telescope expansion joint.

The expansion joint (Fig. 6 elevation and Fig. 7 section) consists of a large casting having two longitudinal holes, into which the ends of the supply pipe and return pipe are introduced. At one end of the casting these holes are supplied with threads *E''*, Fig. 7, and the ends of the pipe are screwed into them in the same way that they are introduced

FIG. 6 EXPANSION JOINTS.



into an ordinary coupling. By this means, as the expansion joint is firmly bolted to the masonry foundation, the joint forms an anchorage, so that one end of the section of pipe to which the joint is attached is firmly fixed and held in its place. At the opposite end of the joint from the screw threads, the casting is enlarged so as to receive two sleeves of phosphor-bronze *K*, containing a large percentage of aluminum. These sleeves form the movable part of the joint, and, after being introduced into the casting, are carefully packed with a rope made of pure asbestos fibre, *J*, impregnated with black lead. This packing is introduced between the casting and the phosphor-bronze sleeve in the same manner as ordinary packing is introduced into stuffing-boxes; and the gland *L* is firmly fastened on top of the packing. The outside end of the phosphor-bronze sleeve is furnished with a screw thread *C*, to which the end of the pipe is attached, so that when the pipe expands or contracts, the phosphor-bronze sleeves moves in and out of the casting and accommodates itself to the varying lengths of the

pipe. By means of the gland in the stuffing-box and a corresponding ring *e* on the inside of the casting, the phosphor-bronze sleeve is very carefully aligned, so that its motion in and out is in a straight line. In the joints which we have introduced here, the sleeve of the supply main is long enough to give a motion of 12 inches, while that of the return main is about 8 inches. Inasmuch as these joints are placed, on an average, as often as once in 100 or 150 feet, and the maximum motion

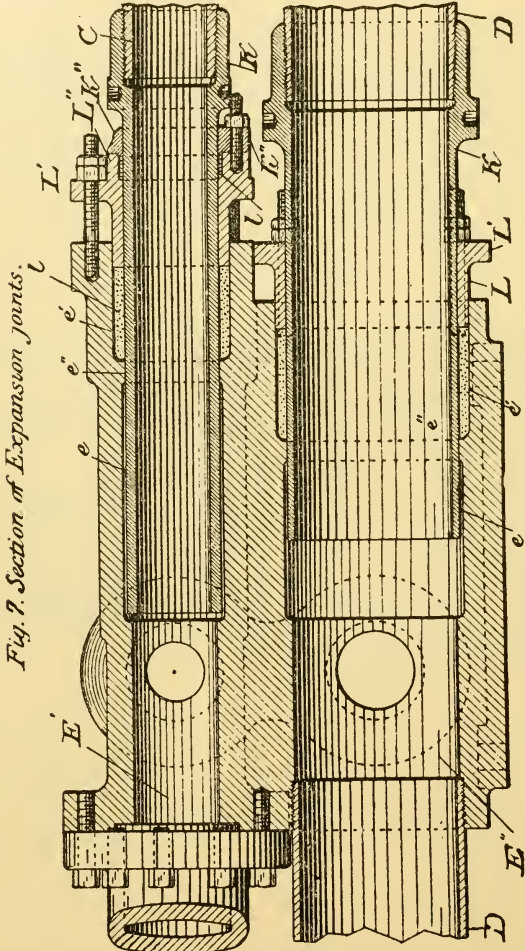


Fig. 7. Section of Expansion joints.

for which they will have to provide being only from 4 to 6 six inches, it will be seen that there is an abundant margin to prevent any possible cramping.

Last spring we built an experimental joint of this kind, and setting it up in our shop in New York, put on a steam pressure of four hundred and fifty pounds to the square inch, and attaching a lever to the sleeve, worked the joint to and fro several thousand times, corresponding to

several thousand expansions and contractions of the pipe. At the end the joint was as tight as it was in the beginning, not leaking a drop.

Each one of the expansion joints is placed in a manhole, so that it is perfectly accessible to inspection or repairs. On the fixed end of the expansion joint there is a valve. The object of this valve is twofold. Beyond the valve, in the casting of the expansion joint; is a side outlet also provided with a valve. In the growth of the system it will soon be necessary to introduce cross pipes extending between the main supply pipes passing through the side streets so as to give a hot water supply to the intervening buildings. For example, there is a manhole at the corner of Devonshire and Franklin streets and one at the corner of Franklin and Congress. At each of these manholes occurs an expansion joint. At any time it is simply necessary to connect this valve at Congress street with the corresponding one at Devonshire street, and then, opening the valves, a stream of hot water would flow between the two streets, making a cross-connection from which the buildings on those streets could be supplied.

When it becomes necessary to repack the expansion joints—though to the best of our belief the packing will last a long time—it is only necessary to shut off the valve at one manhole and a corresponding valve at the next to cut a section of the main out of the circuit; and, by opening a side valve, we can discharge the water contained in the main into the conduit, which is provided with a drain for this purpose, and then, by blowing a stream of air into the manhole, cool it off sufficiently so that the workman can open the gland and introduce a new packing—all in the course of a few hours. It could easily be done at night time when the demand for heat was a minimum.

Many questions have been asked as to the safety of this system—pertinent questions, too, because exaggerated statements have been current as to the pressure which we propose to carry.

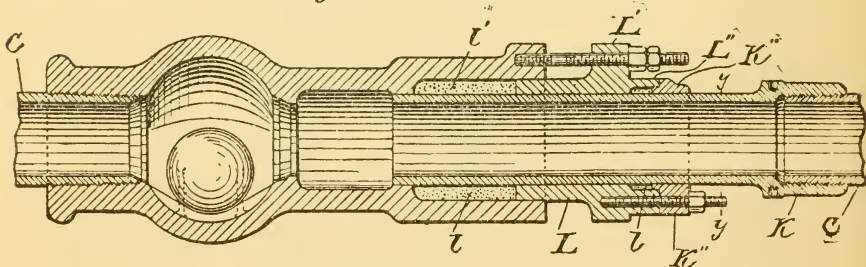
The supply pipe is made of what is called “extra heavy” pipe, the bursting strain of which is twelve thousand pounds to the square inch, as we have ascertained by testing a number of samples to destruction. Every piece of pipe that has gone into the streets has been tested to four thousand pounds to the square inch as a proof test. After the main is laid in place every section—that is, the distance from one expansion joint to the next one—every section, including all screw-threads, all of the packing of the expansion joints and all joints, has been tested to fifteen hundred pounds, and now that the main is completed, we are at the present time making a test of the whole main up to fifteen hundred pounds, from the station round back to the station again. So, when the main is completed and ready for use, it will have received, first, a test at the mill of four thousand pounds; second, a test, by sections, of fifteen hundred pounds, and, third, a test of the main as a whole of fifteen hundred pounds, all being pressures per square inch.

We expect to deliver water to our consumers at a temperature of about four hundred degrees, with corresponds to two hundred and fifty pounds to the square inch absolute, two hundred and thirty-five above the atmosphere. Probably the water will have to leave the station slightly higher than that to provide for the unavoidable radiation. If we send

the water from the station at three hundred pounds to the square inch, and allow one hundred pounds for pumping friction, the total pressure on the main would not exceed four hundred pounds; and, as the main has been tested to four thousand pounds, there is a larger margin of safety.

As an additional precaution, we have, once in every section, a check valve, so arranged as to shut off automatically each section of the main in case of any accident. Malicious injuries might occur, for it is conceivable that in times of strikes men might dig up the main or drive a pick into it. In the illustration, Fig. 8, a cross-section of this valve is shown in connection with the expansion joint. It will be seen that on the left hand side of the joint the casting is enlarged so as to form a spherical cavity into which one end of the pipe line, *C*, is screwed in the same manner as into a regular coupling. The spherical cavity contains a ball supported on two ribs so planned as to allow the ball when at rest to remain at the bottom of the cavity. The end of the pipe *C* is chamfered so as to form a valve seat. Under ordinary

Fig. 8. Automatic Valve.



circumstances, the ball remains at rest on the ribs. Should, however, any rupture occur, the current of water flowing through the main will, by reason of the break, be greatly accelerated, and acting on the ball cause it to roll up along the ribs and seat itself on either side of the spherical cavity toward which the current may be flowing, thus completely shutting off the remainder of the main. The forces keeping the ball in equilibrium are its weight, acting downwards and keeping it in place, and the friction of the water current tending to force it up to the inclined ribs and seat itself against either side of the spherical cavity; so, by varying the weight of the ball, the valve can be adjusted so as to close with almost any desired velocity of current. Under maximum demands, we can use a current of 10 or 15 feet a second, and the ball is so weighted as to close at a velocity of 20 feet a second. Should a rupture in the pipe occur, giving a velocity of 20 feet a second, the ball will leave its place, and, rushing up, close the end of the pipe and shut off the rest of the main. This is not simply theory, but is practice to the extent that we have made a number of these valves, and, after experiment, have found them to work very accurately.

Should any accident occur, either malicious or otherwise, to rupture the main, it is obvious that only the quantity of water contained between two check valves would escape from such a break. As these

valves are placed at intervals of about 100 feet, the amount escaping would not exceed 20 cubic feet. The volume of the conduit is so large that should this entire quantity of water be discharged into it the steam formed therefrom would be quickly dissipated through the length of the conduit without producing sufficient pressure to do any damage.

The conditions which surround a pipe in the street are so different from those to which boilers are subjected, that a little consideration will show an explosion of the pipe to be an impossibility. A boiler, with its setting of masonry and bed of incandescent coal, is encompassed with a highly heated atmosphere which constantly tends to supply it with more and more heat. The street pipe, on the other hand, is *hotter* than its surroundings. On the occurrence of a slight rupture in the shell of a boiler, the pressure is relieved from the large mass of water therein contained and an outflow of the boiler contents established through the incipient opening.

The large diameter of the boiler shell permits the molecules of water flowing towards the incipient rupture to attain, before reaching it, a very high velocity; while the hot masonry surroundings, and especially the glowing coals and incandescent gases of the furnaces, furnish to the water continuous supplies of heat, maintaining the pressure and accelerating the rushing molecules. So, in far less time than it has taken to describe this action, the current of steam and water has attained such velocity that its impact has been sufficient to rend the boiler, and perhaps overthrowing the masonry, hurl it hundreds of feet from its original location. In the street pipe, the comparatively small diameter precludes the possibility of a high velocity in the water current, even should an opening occur. Furthermore, as no supply of heat is furnished to the water, the pipe being surrounded by the comparatively cold conduit every unit of steam formed abstracts and renders latent the heat from five units of water. Thus even if a rupture occurred in the pipe, no disastrous explosive action would follow, a simple tear through which the water would slowly escape into the conduit being the only result.

Before passing to the house connections between the main and the buildings, allow me to call your attention to the special screw thread which we have used in making the joints in the streets with the two-fold object of securing extra strength and greater tightness.

Ordinarily, a screw thread, as is well known, reduces the strength of the pipe or rod on which it is cut about 30 per cent. In Fig. 9 the special thread used in our plant is exemplified. The coupling joining the ends of the pipes *B* and *C* is made considerably longer than is customary in ordinary pipe fittings. For a little ways the end of the coupling is bored out so as to be a fairly accurate fit on the end of the pipe. This greatly improves the joint, as the over-lapping end of the coupling tends to strengthen and support the pipe that is introduced into it.

The special peculiarity of the thread to which I wish to call your attention, however, is that portion between the points *b b'* and *c c'*. It will be seen that the top of the thread is in a straight line with the outside of the pipe, while the bottom of the thread, between the points *b b'* and *c c'*, is inclined to the axis of the pipe at a considerable angle, so as to cause it to run out or vanish at *b'* or *c'*. By this means the weakening of the

pipe caused by the cutting of the thread is spread out and diffused over a considerable length; and, by proportioning this vanishing of the thread in a proper manner, experiment has

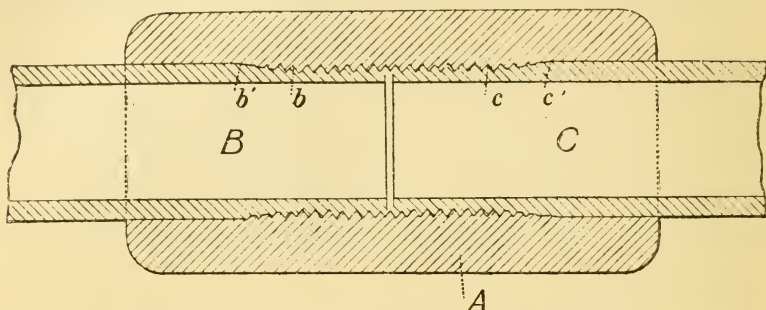
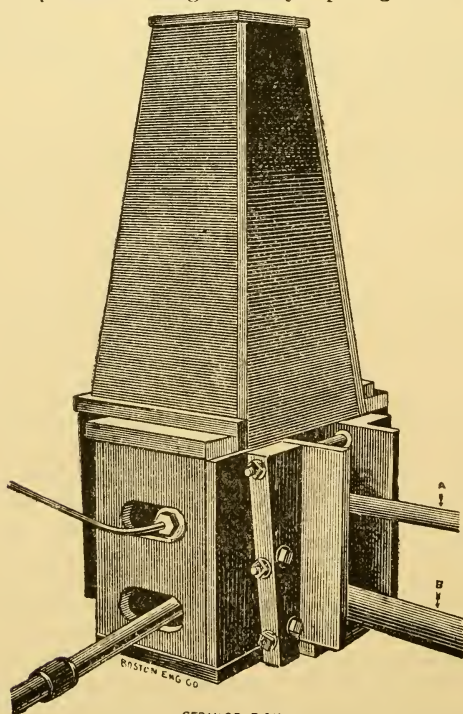


FIG. 9. SPECIAL THREAD.

shown that it has been possible to preserve ninety-seven per cent. of the full strength of the pipe. In addition, this vanishing of the thread produces a long and very tapering cone, which may be



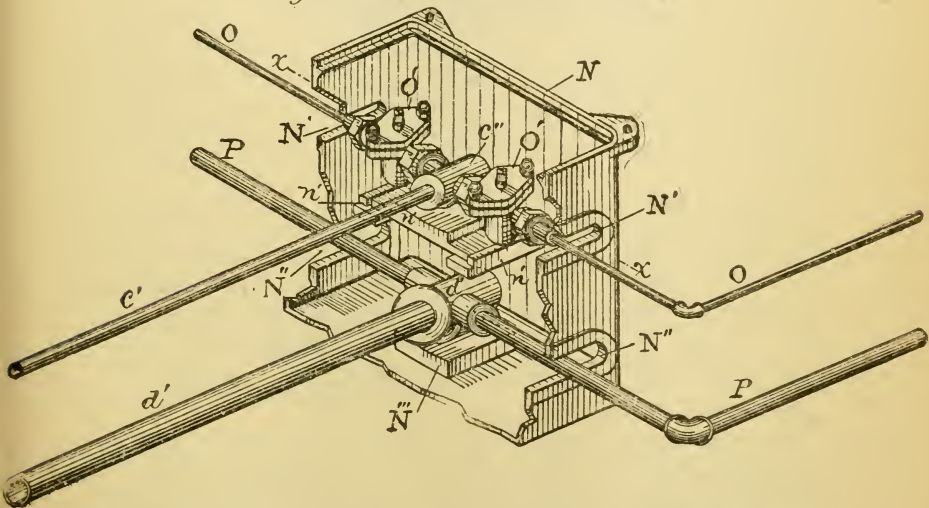
SERVICE BOX

forced into the coupling by means of the pipe tongs in such a way as to actually bed the metal of the pipe into that of the surrounding coupling and make a joint which is absolutely tight. This same result is attained

in a less degree with the ordinary pipe thread, but inasmuch as the cone produced by our special thread is very much smaller angle than that used by standard pipe fittings, the pressure of the tongs in making up the joint causes it to bed more firmly into the metal of the coupling. The rolling mill supplies pipe in lengths of about twenty feet, so that the necessity of securing a perfectly tight connection between each length is very apparent. With this form of thread our experience has demonstrated that, even under 1,500 pounds, it is perfectly possible to secure absolutely tight joints. In testing the sections, we have never found a leak when the joints were properly made.

Each coupling also forms an opportunity for a house connection. On either side of the coupling a boss is cast. For the house supply inch pipe is used, and for the return two-inch pipe, which extends from the main to the sidewalk on either side of the street, passing through a box made of crosstied yellow pine. At the sidewalk a service box (shown in elevation in Fig. 10 and section Fig. 11) is situated. In Fig. 10 the supply pipe may be seen at *A*, while the return pipe is indicated at *B*. These pipes *A* and *B* enter the box and there terminate in a three-way tee provided with asbestos cocks, by means of which the supply from either branch of the tee can be at pleasure controlled. By means of this three-way tee and

Fig. 11. Interior of service box.



its asbestos cocks, each service box is enabled to supply three houses. From the service box to the inside of the house wall—usually a distance of not more than eight feet—copper pipe is employed in preference to iron pipe. The advantage of copper pipe in this location is very obvious when it is considered that, owing to the ductility of this metal, the pipe can be bent in any desired shape without the necessity of special fittings, involving the construction and maintenance of a large number of joints. So by using, from the service box to the inside of the house wall, a copper pipe, we are enabled to introduce in it as many bends and carry it around as many corners as may be necessary.

The size of copper pipe which we most frequently used is quarter inch which is amply sufficient to supply ordinary buildings. In the case of large stores or warehouses, three-eighths or one-half inch is employed. While, where it is desired to supply power to an engine of 25 or more horse-power, five-eighths or three-quarter inch pipe is employed. A one-inch pipe, such as you see here, would be ample to supply so large a building as the Post Office. All of these samples of copper pipe which you see here, have been tested to over 6,000 pounds. The sample of one-inch pipe split at 6,200 pounds, while the smaller size held 7,000 without showing any signs of failure.

The water, as I have already shown, is merely the vehicle for the transportation of heat. And now having indicated the method by which we introduce it inside a customer's wall, the question arises, how can it be used?

Very broadly, it may be stated that our service is perfectly adequate to afford a supply of heat for any purpose whatsoever requiring a temperature of 400 degrees or less, whether it be for heating, power, cooking, chemical operations, or any branch of manufacturing. The various appliances, however, by means of which the heat contained in the water may be utilized, are as varied as the different branches to which it may be applied.

For heating simply two plans present themselves. Hot water can be introduced directly into a radiator, which may occupy the same position that the present furnace in the house takes up, and may warm a quantity of cold air supplied through the cold air box, and send that air heated through the flues that are already in place, so as to warm the building in the same way that the furnace does at the present time, only substituting a hot watercoil for the glowing mass of incandescent coal.

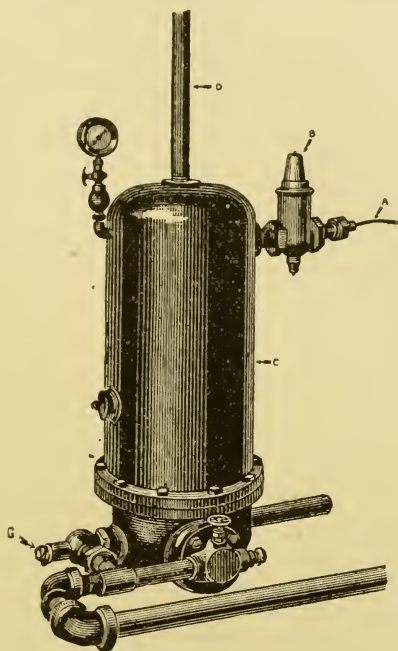
Where the edifice is already piped for steam, or in case of a set of offices where a very varied supply is desired, steam heating in the usual manner may be resorted to by the introduction of a device called a "converter." This contrivance, shown in Fig. 12, may be very briefly described as a steam dome, for in reality in our system it occupies the same place that a steam dome does in a boiler. If, in imagination, you will conceive an ordinary boiler to be stretched out so as to occupy two miles of space, you will have a very fair conception of our system as applied to the distribution of steam heat.

The end of the copper pipe *A* as it comes in from the street is attached to a reducing valve *B*. This reducing valve we make of rather peculiar construction, so as to specially adapt it to withstand the pressure to which it is subjected and also to afford a regulator of unusual sensitiveness and durability. By means of the pressure reducing valve, most of the pressure on the water contained in the copper pipe is removed and the water allowed to flow into a large iron receptacle *C*, which forms the steam dome proper. By the removal of the pressure a part of the water is thereby permitted to take up the superfluous heat and to expand into steam.

On the left-hand side of the converter a small steam gauge is shown, the purpose of which is to constantly record the pressure to which the

converter is subjected, and to enable the reducing valve to be set so as to give a pressure of any desired amount. In the top of the converter a steam pipe *B* conveys the steam away as fast as it is formed, and carries it to any part of the building where its use may be desired. At the bottom of the converter a return pipe *E* may be seen connected to a float-trap placed on the inside of the converter. Another pipe *F* is used to convey back to the converter the condensed water from all of the radiators, so that there may be little or no loss in the system. As fast as this condensed water accumulates in the converter the trap previously alluded to discharges the water from the return main *E*, and allows it to flow into the main in the street, whence it is conducted to the station.

As a precautionary measure, a safety valve *G* is attached to the con-



THE CONVERTER

verter so that in case of any failure of the reducing valve to act in a proper manner, which might possibly allow a greater pressure to come on the converter than is intended, this safety valve will open and permit the contents of the converter to flow into the return main, and relieve itself entirely.

For supplying steam to an engine no change is made in the converter excepting to enlarge it sufficiently so that there may be a sufficient quantity of steam always on hand ready to supply the cylinder of the engine. We generally calculate that, to preserve an adequate supply, it would be necessary to have the volume of the converter at least ten times that of the cylinder of the engine which it is designed to feed. So, for a large engine, we merely increase the size of the iron dome to such propor-

tions as shall always preserve the requisite amount. For any cases where both heat and power are desired in the same building, as frequently occurs, we use a compound converter with two reducing valves so arranged that the water first introduced from the street shall expand into one chamber, giving, for example, a pressure of 60 pounds of steam for the purpose of driving an engine. As soon as the water, under the pressure of 60 pounds, is discharged from this first chamber in the converter, by means of the trap, it is received in a second one where, by means of an additional reducing valve, the pressure is again reduced and the remaining portion of heat contained in the water allowed to expand a part of it into steam, which may be used for heating. By this means we are enabled to reduce the temperature of the water to the greatest amount, thereby returning it to the station as cool as possible.

In a system of this kind protection from radiation is an exceedingly important consideration. After a number of exhaustive experiments on nearly all of the non-conducting coverings now in use, we decided to adopt a covering made of asbestos. The covering is simply a roll of pure asbestos fibre $1\frac{1}{2}$ inches thick. It is made by taking the asbestos from the mines, carding it in the same way that cotton wool is carded, and winding it around a cylindrical roll. After the mixture is dry a saw is run along the side of the roll, cutting the covering in two; then the roll is opened and it is taken off. On the outside of the asbestos is a solidly woven cloth made of asbestos rendered waterproof by an admixture of plaster of Paris, and held in place by wire netting.

Returning for a moment to the section of conduit, Fig. 5, we have in the centre the pipe itself; outside of the pipe an inch and a half of asbestos with a water-proof asbestos covering. An air space of 4 inches separates the asbestos from the first brick arch, then a second air space of 2 inches and a second brick arch. So we think the system is about as thoroughly protected from radiation as could be done. As to the insulating power of the asbestos this experiment may be interesting:

I had an air-bath made, so arranged that it could be kept at a constant temperature of 500 degrees Fahr. A sheet of the asbestos covering, just as you see it, was laid on top of the air-bath. In contact with the upper side of the asbestos a piece of 2-inch yellow pine plank was placed so as to cover the sheet entirely. Between the asbestos and the plank a second registering thermometer was introduced, so that the temperature between the asbestos and the plank could be accurately ascertained. The experiment was continued for several days, during which time the air-bath was constantly maintained at a temperature of 500 degrees, and the highest temperature ascertained as occurring between the asbestos and the wood was 158.

The relative cost of transporting heat from point to point is a most important consideration. Suppose that it is wished to maintain at any place a constant temperature. It may be a radiator for steam heating, or a cook stove or steam engine. If we have a vessel in which we wish to maintain a constant temperature, it is necessary to supply the heating medium to that vessel at a higher temperature than that at which it is to be sustained, and the greatest economy of maintenance is only achieved by supplying the medium to the vessel at the highest possible temperature

and exhausting it therefrom at the lowest. In other words, to furnish the least quantity of the circulating medium with the greatest possible fall in the temperature. If we supply a pound of water, we will say at 400 degrees, and let it cool down to 200, we get 200 units of heat; if we supply it at 300 and allow it to cool down to 200 we get only 100 units of heat. So that in the practical operation of a system of this kind the aim should be to introduce the circulating medium at the highest temperature and reduce it to the lowest. The temperature required for cooking is about 350 degrees, and it is probable that this demand is the most severe that can be made on the system; and for a discussion of the relative advantages of water over steam as a medium for the transmission of heat, I have selected this as being the one that would present the system in its worst light.

If a range is to be maintained at a temperature of 350 degrees, it is proposed to supply water at 400 degrees. Suppose there is introduced into the range a cubic foot of water at 400 degrees. The weight of the cubic foot of water is 53.63 pounds. If the temperature of the range is to be kept at 350 degrees the water can only be allowed to fall 50 degrees. The fall in temperature is, therefore, 50 degrees. The whole quantity of heat liberated by the fall of the water is 53.63 times 50 times 1.0174 or 2,728 ($53.63 \times 50 \times 1.0174 = 2728$) heat units.

The medium which is most commonly used instead of water for the transmission of heat is steam. Supposing, instead of admitting to the vessel a cubic foot of water we admit therein a cubic foot of steam at the same temperature of 400 degrees. That cubic foot of steam weighs .547 pounds. Now, if that steam falls from 400 to 350, a portion of the steam is condensed and the latent heat liberated. A cubic foot of steam at 400 degrees weighs .547 pounds, and at 350 degrees it weighs .3056 pounds, the difference between the two is .24 pounds. The latent heat of evaporation of steam at 400 degrees is about 830 units per pound, therefore by multiplying 830 by .24 we obtain a product of 199.2 as the number of heat units set free by the fall in temperature of a cubic foot of steam from 400 to 350 degrees. It has been seen that the cubic foot of water will deliver 2,728 units of heat, while the cubic foot of steam yields 199. The ratio of these two quantities is 1 to 13.7.

Hence it is obvious that 13.7 cubic feet of steam must be circulated to do the same amount of heating as may be accomplished by 1 cubic foot of water. Just as soon as the steam has fallen to the temperature at which it is required to maintain the range, the steam must then be exhausted to give rise to a new supply. It is true that steam being a light, aeriform fluid, will flow through pipes more easily than water will.

By the well known laws of hydraulics, the relative velocities at which fluids travel through pipes vary inversely as the square root of the densities. The relative density of water to steam is as 1 to 9.87. Consequently, under the same conditions, with the same length of pipe, the same resistances in the pipe, and the same pressure on the circulating medium, 9.87 cubic feet of steam would flow to 1 cubic foot of water. But the water is to the steam, as far as heat carrying power is concerned, as 1 is to 13.57; whereas the relative quantities which

would be transmitted through a pipe are as 1 to 9.87. The expense of delivering to a distant point any fluid depends simply upon the amount of mechanical work necessary to overcome the resistance of the pipe. The relative velocities at which water or steam will flow are as 1 to 9.87; but the relative quantities necessary to deliver the same quantity of heat are as 1 to 13.7, hence the current of steam must have a velocity of .135 times that necessary for the water current. Remember that the transmission through a pipe is not a question of weight, but a question of volumes. A 4-inch pipe will carry no more cubic feet of mercury than it will of hydrogen gas, although the density of the mercury is several thousand times that of the hydrogen. It will carry more pounds of mercury, but no more cubic feet. So to deliver equal quantities of heat there must be in the case of steam a velocity of about .135 times that of the water. The mechanical work, which is the measure of the expense of transportation of a fluid, varies as the cube of the velocities at which the fluid flows. We have seen that under similar circumstances if the velocity of the water current is 1, the velocity of the steam current to transmit an equal amount of heat must be 1 and 35. Cubing, it is obvious that the relative expense of transporting equal quantities of heat by steam or water will be as 1 to $2\frac{1}{2}$.

It is usually assumed that a current of steam flowing through a pipe is maintained by the expansive force in the steam itself. Precisely; but this expansive force in the steam is only attained by a fall in pressure and temperature, and consequently by a corresponding amount of condensation.

Returning to our former example, if, at the end of a long line of pipe, it is wished to deliver steam at a temperature of 400 degrees, corresponding to a pressure of 250 pounds to the square inch, it would be necessary at the central station to put upon the boilers a sufficient pressure in addition to that at which it is expected to deliver steam to overcome the inevitable friction of the pipe between the boilers and the place where the steam is to be received. In a long line this friction is of considerable amount, so that in order to accomplish the necessary delivery of steam the boilers would be called upon to bear a burden equal to the amount of radiation of the line plus the amount of frictional resistance offered to the steam current. The frictional resistance may of course be reduced to a minimum by the use, in line, of pipes of very large diameter. This has frequently been done, with the inevitable result of very largely enhancing the cost of the plant and increasing the difficulties both of construction and maintenance.

In the case of the water plant, it is only necessary to subject the boilers to the pressure requisite to give the temperature at which it is wished to deliver the water plus the much smaller amount of radiation which takes place from a pipe of less diameter than that employed in the steam plant, the frictional resistance of the pipe being entirely overcome by means of the forced circulation obtained by the pump. The boilers, which perhaps are the most difficult part of the system, being entirely relieved from this extra pressure, are much more easily constructed and maintained. Thus by means of the use of an incompressible fluid like

water, and the employment of a pump to produce circulation, a much higher initial pressure can be placed upon the pipe line to overcome the frictional resistances of the pipe, thus enabling us to employ a very much smaller pipe than is customary to use in steam plants, and largely decreases the expense of the system and the difficulties of construction and maintenance.

Even to engineers too much mathematics is provocative of a certain kind of madness, which I am fearful my insipid figures may have already induced. Alas! that I have not the brush of an artist or the tongue of an orator to adequately depict for you the future which we believe will grow from the germ that last summer, 'mid trouble, confusion and annoyance, we have planted in the subsoil of the Boston streets.

We dream of a tropical future from which dust, ashes and smoke are banished; of chimney-less houses, from the cellars of which the black diamonds of the present are exiled, giving place to paper and paint, and becoming habitable.

We dream of matrons made happy by the absence of dust, on whose carpets no particle of ashes ever lights; and yet whose houses are as balmy as the air of the tropics; whose range is never cold; whose ovens never refuse to bake; nor is the good man's wrath ever provoked by the tardy breakfast, the fault of the over-sleeping domestic; for, Lo! in an instant, by a touch on a valve, the range glows with heat, and winter or summer, early or late, the ovens, at a constant and equable temperature, never refuse to fulfill their duty on the minute.

Who knows! Ten years ago, when the first squeaky voice pulsed across Machinery Hall, Boston little dreamed that now it could talk to Chicago. In comparison with the electrical wonders of the past decade, our most sanguine expectations seem easy of realization; and when achieved, Boston may again take to herself the credit, as she has often done in the past, of being the successful pioneer in a new field.

FEBRUARY 10, 1888.

POSTSCRIPT.—The main and station of the Boston Heating Company was completed and in readiness to commence circulation about the middle of December. The pipe line, after being tested from the station round to the station again, was thoroughly washed out to remove all dirt and grease, by pumping water through it for two days. The main was then connected with a battery of boilers of 200 horse-power, underneath which a slow wood fire was started, so as to gradually heat the water contained in the boilers. A steady circulation was at the same time maintained through the whole of the main, so that as fast as the water was warmed in the boilers, it might be sent out into the main, thus gradually heating the whole system.

About ten day was consumed in warming the main up to the temperature of about 380 degrees. During this time the whole line was carefully watched to ascertain whether any leakage developed, and whether the expansion joints worked in a proper manner. No trouble of any kind was experienced, the main under heat being found to be fully as tight as it was under cold water pressure. All of the expansion joints operated as had been anticipated, taking up the expansion, as the

temperature increased, in a perfectly satisfactory manner. After the temperature of 380 degrees was attained, a solution of potash was pumped into the mains and circulated for several days in order to remove all grease and red lead, so that the system would be full of clean water. After two or three days' circulation of potash water, the main was cleaned by allowing the hot potash water to escape, and replacing it in the boiler with fresh warm water. This cleansing of the main was continued until the water showed no signs of potash or grease.

After this thorough cleansing had taken place, the various consumers, whose house connections had been made, were, one after another, turned on to the line, and at the present time the company is heating about twenty-five large buildings and supplying power to some engines.

So far all the consumers on the line have expressed complete satisfaction with the service rendered to them. Experiments on the losses by radiation show that the steam furnished is exceptionally dry. One engine is run from an exposed pipe over 60 feet from the converter, and no trouble whatsoever is experienced with water in the cylinder, showing that even when the steam is exposed to this amount of radiation it is as dry as steam furnished by ordinary boilers.

STADIA MEASUREMENTS.

BY JAMES RITCHIE, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.
[Read February 28, 1888.]

Stadia measurements were first used in 1820 by an Italian engineer. In 1836 they were used in the topographical and military survey of Switzerland, and in 1850 they were introduced in this country by Mr. J. R. Mayer, a civil engineer, who brought the method from Switzerland.

It is not necessary to go into the theory of stadia measurements except so far as will show the fundamental principles of the same. The accompanying demonstration is taken from J. B. Johnson's work on "Transit and Stadia."

Let LS (Fig. 1) be the objective lens of the telescope, F the position of an image for parallel rays, that is of an object at an infinite distance. Let C be the centre of the instrument, or the intersection of the plumb line (extended) with the axis of the telescope. Let E_1 and E_2 be the "principal points" and let the distance $FE_1 = f$ (the focal length), and $\left\{ \begin{array}{l} IE_1 = f_1 \\ OE_2 = f_2 \end{array} \right\}$ conjugate foci. Let $A_1B_1 = i$ —for image—intercepted portion and $A_2B_2 = s$ —for stadia—intercepted portion.

Since A_1E_1 is parallel to A_2E_2 and B_1E_1 to B_2E_2 we have $A_1B_1 : A_2B_2 :: IE_1 : OE_2$ or $i : s :: f_1 : f_2$ (1). Also from the law of lenses $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f}$ (2). Since the distance $FE_1 = f$ is constant for any lens or fixed combination of lenses, we see from (2) that if the object approaches the lens the distance f_2 is diminished and f_1 is increased. If the extreme wires in the telescope be supposed to be placed at A_1B_1 in the figure, then $A_1E_1B_1$ is the visual angle and is equal to $A_2E_2B_2$.

But as the image changes its distance from the objective as the object is nearer to or farther from the objective, the distance $I E_1 = f_1$ is variable while $A_1 B_1$ is constant for fixed wires. Therefore the visual angles at E_1 and E_2 are variable. If these angles were constant the space intercepted on the rod and the distance of the rod from the objective would

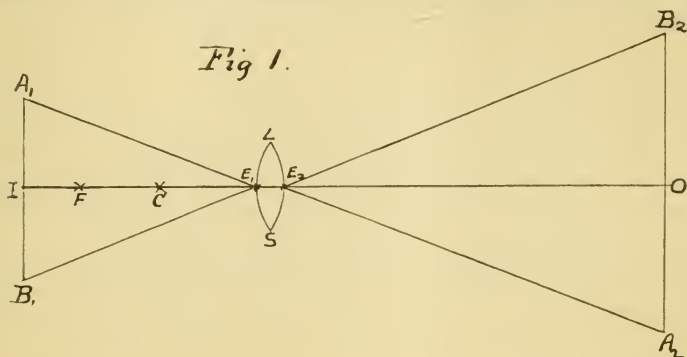
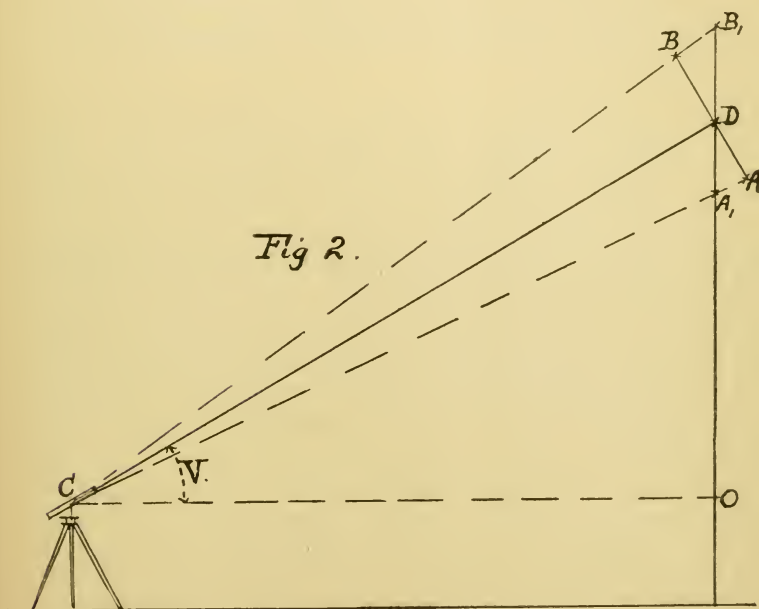


Fig 2.



be in constant ratio. This is not the case, however, and the relation between the distance $O E_2$ and the space $A_2 B_2$ on the rod may be found as follows :

From equation (1) we have $\frac{1}{f_1} = \frac{s}{i f_2}$ and from equation (2) $\frac{1}{f_1} = \frac{1}{f} - \frac{1}{f_2}$. Hence, $\frac{1}{f} - \frac{1}{f_2} = \frac{s}{i f_2}$, or, $f_2 = \frac{f}{i} s + f$. That is, the

distance of the rod from the objective is equal to the intercepted space s multiplied by the constant $\frac{f}{i}$, plus the constant f , where f is the focal length and i is the distance between the extreme wires.

If the distance is to be reckoned from the centre of the instrument, as is customary, let this distance $= d$, and the distance from the centre of the instrument to the objective $= c$ ($C E_2$ in the figure), then $d = f_2 + c = \frac{f}{i} s + f + c$.

To find the constants f , i and c we first measure the distance from the centre of the instrument to the objective, which gives the value of c ; then focus the objective on some distant object, as far distant as possible, and measure the distance from the plane of the cross wires to the objective, which will give the value of f ; then setting up the instrument, measure forward a distance $= f + c$ as already found, and from this point thus obtained, measure forward a base line of any convenient length. Hold the rod at the extremity of this base and measure the space intercepted by the extreme cross wires. Call the length of the base $= b$ and the intercepted space $= s$, then $b = \frac{f}{i} s$, or $i = \frac{s}{b} f$. If it is desired that $\frac{s}{b}$ should equal $\frac{1}{100}$ (as is customary), then the wires must be apart a distance $i = \frac{1}{100} f$.

Stadia rods are graduated to suit the instrument with which they are to be used, but ordinary level rods may be used, care being taken to add the constants ($f + c$) to the distance given by the rod. In graduating the stadia rods there are various methods used for obtaining accurate results, but the method used most generally is as follows: A base line is measured, whose length should be that of the average sight it is desired to take. The instrument being set at one end of the base, the rod is held at the other, and the intercepted distance on the rod is marked and then divided up as finely as it is desired to take the readings, and the divisions extended to the limits of the rod. This rod is only absolutely correct for the same distance at which it was graduated, but may be used without sensible error for longer or shorter distances.

In making surveys with the stadia it is considered best to use an inverting telescope, as the great point is to be able to see clearly and distinctly the symbols on the rod; and the direct telescope, requiring the use of an additional lens, does not have as clear a field as the inverted. The telescope should have a vertical circle attached firmly to the axis, and it should be in perfect adjustment, as the accuracy of the results depends largely upon the correct use of the vertical circle. The horizontal circle should be graduated one way from 0° to 360° . It is customary to start from a known bearing or azimuth, and continue the main line of the survey by azimuths until some other known point is reached from which a check upon the bearing may be obtained.

Whenever a sight is taken for a stadia measurement, the horizontal angle or azimuth, the vertical angle and the distance, must be read and

recorded. The main line should have the stadia rod and the vertical angle read on the backward sight, as well as the forward, in order to check the work. The sketches in the note-book should show clearly the general outline and features of the country and the location of each stadia measurement.

The field work of a stadia survey may be done very rapidly and with sufficient accuracy for any topographical work, as well as for preliminary surveys of railroad lines, provided in the latter case that it is not desired to make an estimate of cost of construction, in which case I should prefer the chain survey, followed by an accurate line of levels. The stadia is often as reliable for elevations as an ordinary line of levels would be, but I should not like to trust entirely to its accuracy, but should accompany it with a flying level party to check each main point. The distances measured by the stadia are the actual distances between the instrument and the rod, and must be corrected by multiplying by the cosine of the vertical angle. Also, there is another correction due to the rod being held in a vertical position instead of being perpendicular to the line of sight.

Let AB (Fig. 2) represent a rod held perpendicular to the line of sight CD , and let A_1B_1 be a rod held vertical, then the angle $AD A_1 = DCO = V$, the vertical angle. Then $AB = A_1B_1 \cos V$, and $CD = \frac{f}{i} A_1B_1 \cos V + f + c$. But the distance CO is what is desired, hence we have $CO = CD \cos V = \frac{f}{i} A_1B_1 \cos^2 V + (f + c) \cos V$, and the difference of elevation $OD = CD \sin V = \frac{f}{i} A_1B_1 \cos V \sin V + (f + c) \sin V$.

From these formulæ tables have been calculated giving the horizontal distance and difference of elevation for each minute of vertical arc for 100 feet slant distance. With these tables the correct horizontal and vertical distances can be rapidly computed from the field notes and plotted on the map.

Stadia measurements are used by the United States Coast and Geodetic Survey, by the United States Lake Survey and the Mississippi River Commission in completing their topographical surveys, but they are always used in connection with a careful system of triangulation and check levels. In obtaining the outline of river banks, islands, sand bars, or in location of contour lines, I should use the stadia in preference to any other method. As to accuracy of closing, I have run lines along the bank of the Mississippi River from one triangulation point to another, a distance of about 10 miles, and not varied in closing on the second triangulation point more than two meters, that is about 1 in 8,000, which is certainly nearer than it could have been chained. But in making that survey we did not need to use the vertical circle, as the river banks did not vary over three or four feet in elevation in the whole distance. The longest sight taken was 830 meters and was taken from a projecting point of the bank to a similar point, avoiding what would have required two days solid labor to have crossed with a chain, namely, a thicket of young cottonwoods and creeping vines, mingled with fallen

trees, logs and driftwood. In such work there is nothing equal to the stadia for rapidity and accuracy.

In land surveying over rough country or through low brushwood where it would require cutting to use a chain the stadia can be used to advantage. In moderately level country it is full as easy to use the chain. In city work, where great accuracy is required, or in the measurement and staking off of allotments, the stadia is, in my opinion, of no use. Nor could it be used advantageously in locating points whose distances are known, such as staking out a railroad location, setting slope stakes, etc., for the reason that to lay off a distance by stadia requires that the vertical angle shall be known, whereas, we must first fix the point in order to find that vertical angle.

The stadia was used in connection with the plane table, by which some of the most elegant and accurate maps of the Coast Survey have been made. Among the other departments of the government engineers the plane table has been almost entirely superseded by the stadia for filling in the topography of a trigonometrical survey.

In making a preliminary survey for a railroad through very rough country, it would be very easy for an engineer, with three rodmen, to make good progress, and the result would be a reasonably accurate contour map of the region through which it were desired to run the line. But in order that a careful estimate of cost be made, a certain line should be located through said region which should be limited to the grade and curvature desired for the traffic. This would necessitate making a location on the map and calculating from the contours the profile of the desired line. And when this were done your line might or might not come within the limits of grade. In such a case I should, as stated before, prefer to run a chain survey with profile and flying levels, keeping my line where the flying levels showed the desired elevation. With a stadia survey, one does not know anything about his grade unless he should begin at the beginning of his notes and figure up the same from the distances and vertical angles. The same is true of his horizontal distances, unless his measurements have been on quite level ground, when the slant distances will very nearly agree with the horizontal. A vertical angle of $1^{\circ} 46'$ makes a difference of 0.1 foot in 100' in horizontal distance, and a difference of 3'.08 in elevation, according to Professor Johnson's tables, but a vertical angle of twice the size ($3^{\circ} 32'$) gives a difference of 0.38 foot in 100' in horizontal and 6'.15 in elevation, showing that the differences of elevation vary nearly as the angle varies, but that the horizontal difference varies almost as the square of the angle. However, the contour map, if wide enough to plot the line upon under the required grades and curvature, is a very useful factor in the location of a railroad line.

A WELL VENTILATED MINE.

BY LEWIS STOCKETT, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 16, 1888.]

The ventilation of a mine is such a simple matter that I have often thought its very simplicity was one of the great reasons why it is so often neglected, and that if it was a more complex subject, requiring great learn-

ing generally and deep study locally. those who have the matter in charge would be more apt to give it the proper attention that it deserves. The ventilation of a mine consists in passing a current of pure air of sufficient volume through the mine and around the working faces to so dilute all gases, etc., given off as to render them harmless, and mixing in with the air current be passed out of the mine. This is the whole secret of mine ventilation, and to carry it out it is first necessary to have the means of making the air current, and then this having been secured to see that it is properly carried through the mine to the face of workings and wherever needed.

In order to pass an air current through it is necessary that a mine have at least two openings, one for an inlet and the other for an outlet. The current is produced by the difference in density and consequent difference in weight of the air in these two openings. This difference is made by various means, among which are the furnace, steam jet, water fall, steam coil and mechanical ventilators: it is also produced to some extent by the warmer lighter air of the mine being pressed out by the colder heavier air of the atmosphere (in warm weather the action being reversed) producing natural ventilation. Of these the furnace and mechanical ventilators are the ones most in use at present, and the most effective, and in this country the centrifugal ventilator commonly known as the fan is most generally used, for the reason that few of our mine openings are of sufficient depth to make the furnace the more effective.

The difference in pressure of the air in the inlet and outlet necessary to produce a current is so little that it can only be readily measured by the water gauge, which will show the pressure by the difference in height of two columns of water, connected together at the bottom, the upper end of one column being introduced into the air current and the upper end of the other open to the atmosphere. A difference of one to two inches, or from 5.2 pounds to 10.4 pounds per square foot, is sufficient, if the air shaft and air courses are of sufficient size to pass the current and the fan of sufficient size to allow the current to get through it.

Fans are of two general types, the vacuum and plenum, or exhaust and pressure blower, and of each of these types there are almost innumerable forms of construction, as there should be to meet the different duties to be performed in different localities. Of the two general types the plenum or pressure blower is the more effective; this can be proved by a mathematical demonstration and corroborated by actual experience.

By whatever means the air current is produced it is worthless if not properly distributed and carried without loss to where it is needed. This is where the greatest number of failures in ventilation are found, the superintendent, mining engineer, or other in charge considering their duty done in having provided the means of creating the air current and entirely neglecting to see that it is properly taken care of after secured. To properly conduct the current through the mine it is necessary that the mine be opened with that object in view, remembering that an air current requires a return as well as an intake. This is best accomplished by driving all entries in pairs and frequently cross-cutting. If the ventilation of the mine requires such a volume of air as to make the velocity so great as to be an inconvenience to those working

therein, three entries should be driven, and by using one as the inlet and two as the outlet (or *vice versa*), the velocity on the two entries will be about one-half, and on these two entries the work of the mine should be carried on, using the other for an air course alone. This can also be accomplished when there are several districts in a mine by taking a split or portion of the current into each district and not passing the full current around through the whole mine, which will also have the important effect of increasing the amount of air by decreasing the total amount of friction and the velocity at which it travels.

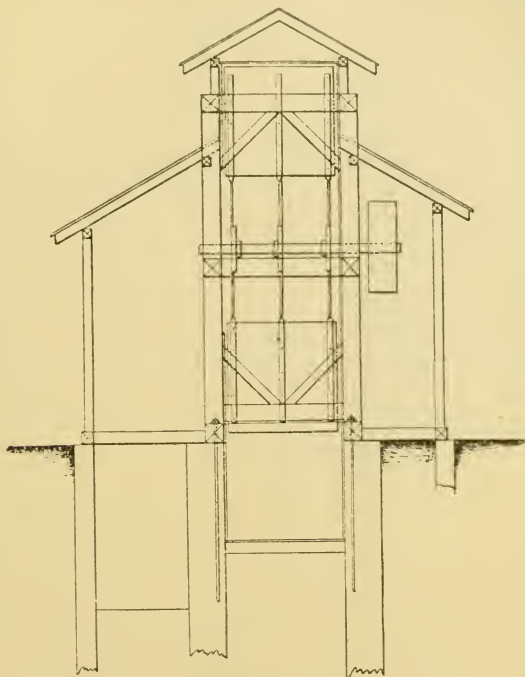
In splitting the air into separate currents, care must be taken that this is not carried to an extreme, and the volume of each current so reduced as to be unable to perform the work required of it.

In passing the air up one entry and down the other of a pair of entries, the frequent cross-cuttings alluded to above are a great source of loss of air through leaks in the stoppings put up in these cross-cuts to throw the air on to the last one opened. It is frequently found that where the air current is more than sufficient at the mouth of the entries, at the face where it is most needed it was very weak or had entirely disappeared. Little leaks all along the line, trifling in themselves but disastrous as a total, were the cause; and where the workings of one district hole through into those of another district is generally found a source of waste. To prevent this every cross-cut should be closed as soon as the one ahead is opened by an air-tight stopping which can only be securely and permanently done by being built of rock or brick laid up in lime and sand or cement mortar, and these occasionally plastered over. And to prevent the leaks from one district to another, where workings have holed through, rooms, breasts, stopes, etc. should be closed up as soon as finished and which will also prevent the gases from old workings escaping into and vitiating the air current.

Doors, curtains, regulators and brattices are used to direct the air current and throw it where it is needed, as to the face of headings, up through working rooms, etc., and when used for this purpose only are very useful in their way. Main air currents should never be separated by a door if it is at all possible to do otherwise; overcasts in the top or undercasts in the bottom, either of timber, rock, or brick are much better, and while the first cost is in excess, the wages of a door tender or trapper saved, soon make them the cheaper. If for local reasons overcasts or undercasts are impossible and the door must be used, two doors sufficiently far apart that in passing through them one can be closed before the other is opened, will prevent the loss of air from the opening of the door and reduce the amount of leakage.

Where the hoisting shaft is one of the openings for ventilation the air current is considerably checked by the cages moving up and down in the shaft; where large hoists are made it takes but little calculation to show that fully one-half of the time of working hours the cages are in the shaft and form a barrier to the air current at the time it is most needed. For this reason a separate compartment in shaft or another opening is essential. When the entries in the mine are small in area, a trip of loaded cars, if moving against the current or more slowly than and with the current, form a very serious barrier to the air, and in mines venti-

lated by only one main current almost stops the flow; to overcome this, whenever possible, the entries or headings should be driven larger than is simply required for the roadway. When the current is in several splits this blocking of the air by trips of cars is not so serious a matter, for if one split be blocked it will increase the volume in another, and it rarely happens that all are blocked at the same moment.



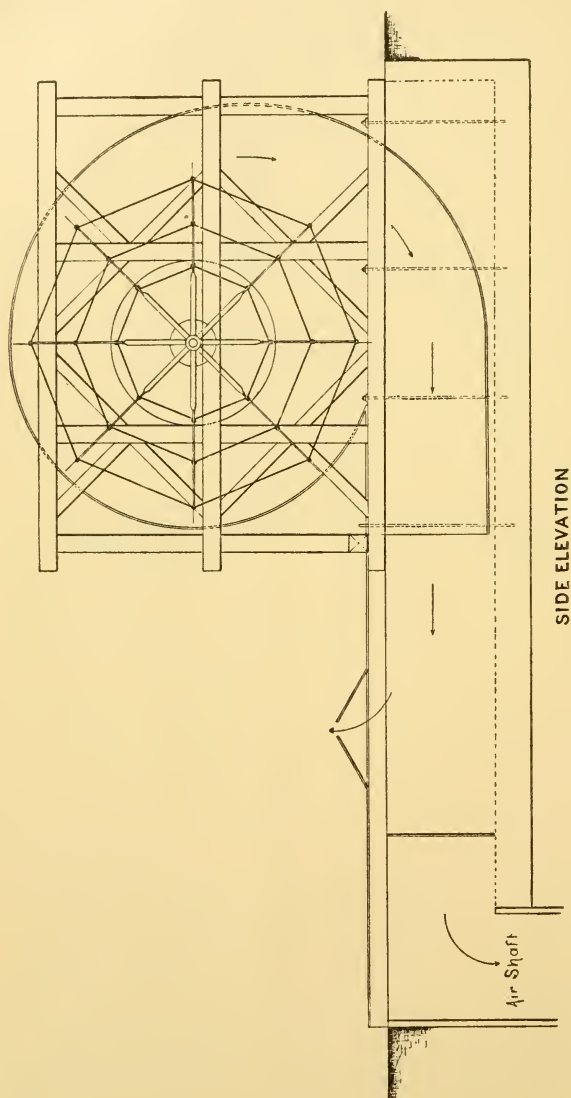
END ELEVATION

20 FT. FAN - NO. 6 MINE

James H. Smith - ENGINEER.

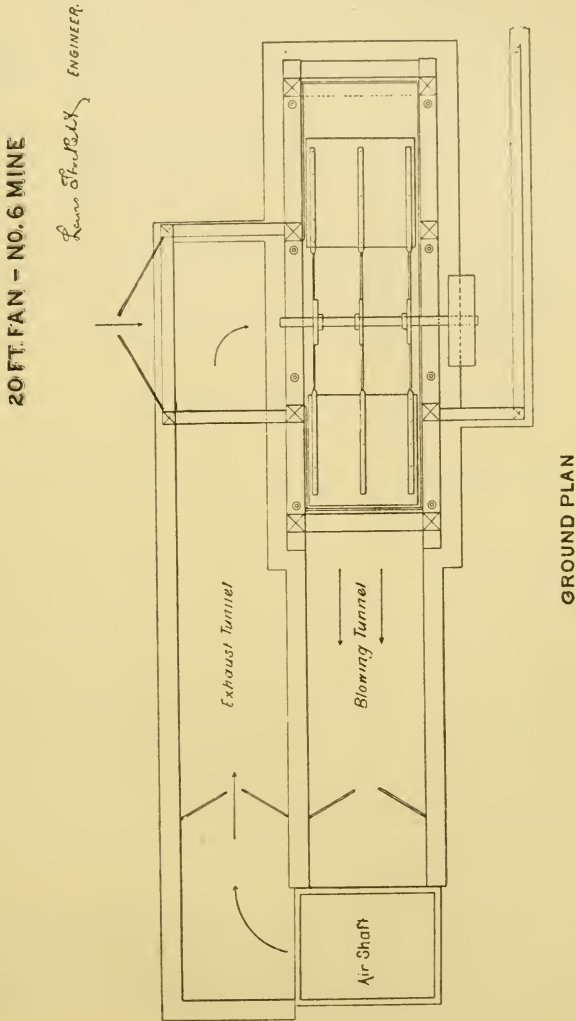
The value of compressed air as a ventilator is made much of by those interested in introducing mining machinery to be driven by compressed air, but when we consider that it is a very large sized compressor that compresses 5,000 cu. ft. of free air per minute, and that this small amount is scattered in very small parts all over the mine and is used irregularly, we can put this factor down for nothing as regards the ventilation of the mine, and as less than nothing if it leads one to suppose that it is ventilating his mine and causes him to neglect other means of ventilation.

In a dry, dusty mine, where the air is constantly filled with floating particles of dust, explosions are likely to and have taken place from the



ignition of the same from an overcharged blast or the firing of some small body of gas. With a proper air current these particles will be carried off, but in some cases it is only overcome by sprinkling the roads

with water from water cars. These cars are arranged with a pump driven by a crank on the axle of the wheels, which will throw water through a hose and enable the top, sides and that part of the bottom distant from the road to be wet down.



Having thus covered the ground somewhat generally, it is part of this paper to present a practical illustration of a mine where the details of thorough ventilation have been well carried out, show the mode of so doing and give the results obtained.

The mine in question is known as Mine No. 6, and is situated on the Wabash, St. Louis & Pacific Railway, near Staunton, Macoupin Co., Ill. The current is produced by a 20 feet in diameter centrifugal ventilator, located at the head of an air shaft $5' \times 8'$, and driven by an engine whose cylinder is $18'' \times 42''$, connected to the fan by a belt. The fan making one and one-half revolutions to one of the engine; the usual speed is 60 for the engine and 90 for the fan; some idea of this speed can be had when it is known that at 90 revolutions the end of the blades are traveling 5654 feet, over a mile a minute, and exceeding the speed of the fastest railroad train.

The fan is so built that it can be readily and quickly changed from an exhaust to a pressure blower, and is so constructed that in all its relations it is equal whichever way it is used. The accompanying drawings will explain this.

The air current is divided into nine separate splits, the volume of each split being regulated to the amount of work being done in each district. This reduces the friction, the great destroyer of an air current, to a minimum, thereby increasing the amount of the air passing, and also reduces the velocity on hauling roads so that a naked lamp can be carried with ease.

Overcasts and undercasts are used wherever they can be to advantage, there being seven in number, and their location is shown by the accompanying map.

The stoppings between main and return currents are mostly of brick and lime and sand mortar, or built up of rock from the roof plastered over.

Old workings have been completely stopped off by brick and mortar stoppings, and the large amount of black damp given off from old gobs kept out of the current. Air courses where not used, as hauling roads have been cleaned up and the area enlarged to pass the current readily without excessive friction.

Further improvements in contemplation and under way are the driving of a main air course to another mine, to make use of an abandoned shaft for the second opening, and overcome the obstruction of the cages in the shaft before spoken of, and enable the escapement ladders and platforms in air shaft to be removed. These ladders and platforms in the air-shaft are a very serious obstruction to the air current, and account for the high water gauge. After these are removed there will be a larger volume of air at the same expenditure of power, or an equal volume at a less expenditure.

The fan running at 90 revolutions as a pressure blower gives a water gauge of $2\frac{1}{10}$ inches, and as the same number of revolutions as an exhaust gives $1\frac{3}{10}$ inches, which will bear out the statement before made that the pressure blower is the more effective as compared with the exhaust fan.

As a pressure blower the fan running free to the open air gave a water gauge of $\frac{1}{10}$ of an inch and a volume of 240,000' of air. With the outlet blocked up the water gauge was $2\frac{5}{10}$ inches or 13 pounds to the square foot for the pressure blower, and $2\frac{1}{10}$ inches for the exhaust fan.

With the fan running at 86 revolutions the following measurements of the volume of the air were made :

Amount of air under fan.....		76,636 feet.
“ “ E. main split.....	35,100 feet.	
“ “ W. “ “.....	40,920 “	76,020 “
“ “ E. return.....	36,450 “	
“ “ W. “ “.....	44,250 “	80,700 “
“ “ E. No. 1 split.....	12,870 “	
“ “ “ “ 2 “.....	6,875 “	
“ “ “ “ 3 “.....	10,800 “	
“ “ “ “ 4 “.....	4,320 “	34,865 “
“ “ W. No. 1 “.....	6,000 “	
“ “ “ “ 2 “.....	11,550 “	
“ “ “ “ 3 “.....	10,125 “	
“ “ “ “ 4 “.....	8,482 “	
“ “ “ “ 5 “.....	1,692 “	37,849 “

The figures, while good of themselves, will be greatly increased when the improvements named above are finished and the job complete.

SHEET OR ASPHALT PAVEMENTS.

At a meeting of the Civil Engineers' Club of Cleveland, April 10, 1888, Capt. D. Torrey, of New York, read a paper in favor of sheet or asphalt pavements compared with stone. The following discussion took place :

Mr. Morse said that sheet pavements were fine pavements if they could be made to last, but that the cost of keeping them in repair was very great.

Mr. Richardson asked if information could not be obtained from London, Paris, Washington and other cities with regard to the durability of these pavements and cost of repair.

Captain Torrey stated that on some of the streets of London that ran from ten to six times the tonnage per foot of width of Superior street in Cleveland, the sheet pavement had been found economical. Leadenhall street in London has never been renewed, but repairs have been made. The oldest pavement of this kind in America has been in use twelve years. The asphalt apparently is not worn at all.

Mr. Richardson said that he had been informed that in Paris small depressions were at once filled up. They were not allowed to grow large.

Mr. Baker asked whether repairs were made in these London pavements by the contractors or by the municipal authorities.

Captain Torrey said that the repairs were sometimes made by the authorities and that sometimes the contractors offered to keep the pavements in repair for a term of years. In Washington repairs are made twice a year, spring and fall. The city of Washington makes a contract for repair twice a year for a five years' guarantee. It costs thirty-three and a third cents per foot—three dollars per yard.

Mr. Morse asked how much it would cost for a guarantee of ten years.

Captain Torrey said that after five years the contractors would agree to repair for ten cents a yard for a long term of years. That includes renewals. The pavement never wears out. A pavement that has been down twelve years is said to be good for twelve years yet. A record

taken from Fifteenth street, in front of the Treasury building, showed the daily average of vehicle tonnage to be 66 tons per square foot. The tonnage on Pennsylvania avenue must be between 40 and 50 tons per day. The tables will show that there is little traffic on the streets of Cleveland except with light weight vehicles.

Mr. Whitelaw asked if new covering could be put on old asphalt pavements.

Captain Torry said that he had never seen this done, but that the asphalt can be easily separated or peeled off from the concrete. If any one could discover a way of warming it up without burning so as to separate, it might be used again.

Mr. Whitelaw said that he supposed that when the asphalt was entirely worn out, the surface might be entirely renewed.

Mr. Morse said that it had been stated that the pavement between Erie and Perry street was much worn. It was not so much worn, but it was uneven in consequence of being taken up to lay water pipes.

Mr. Richardson stated that the St. Paul's Church people protested against the asphalt pavement being taken up and stone laid.

A Voice : There is 75 per cent. of coal tar in that pavement in front of St. Paul's Church.

Mr. Morse said that in some of our light traffic streets a stone pavement would last fifty years. He did not know any sheet pavement that would last half that time.

Mr. Whitelaw said that River street was the first street laid with Medina stone. It was laid in 1857, and he thought the stone would be good to take up and lay again.

Mr. N. B. Wood said that in this discussion no account had been taken of the loss of life of horses and destruction of vehicles. In considering the question of economy of pavement that would last fifty years, it should be asked how many horses has it killed and how many vehicles has it worn out.

Mr. Morse said that it would be difficult to answer that question correctly.

A Voice : Would Captain Torry give as nearly as he can the amount of tonnage carried per square foot per day by the oldest Trinidad asphalt pavement and compare that with the tonnage of the viaduct?

Captain Torry said that a street paved with asphalt in Philadelphia carries 142 tons per square foot per day; that is, about three and a half times the tonnage of Superior street and about four times that of the viaduct. The pavement of Superior street viaduct will have to be taken up and reset before it has carried the amount of the tonnage of the street in Philadelphia.

Mr. Morse said that the stone pavement on the viaduct was laid in the all. It was expected that it would settle, and it has settled.

A Voice: I disagree with Mr. Morse with regard to the inequalities of the pavement over the viaduct being due to settlement. They are caused by the horses' hoofs chipping off the edges of the blocks.

Mr. Morse said that the gentleman was a little mistaken. Blocks of stone in the railroad track were worn turtle back, but in other places the pavement was worn smooth.

Mr. Baker said that the convenience of persons who were taxed on the abutted property should be considered.

A Member stated that he had recently interviewed a number of people in Buffalo and found that the persons who wanted most the Trinidad asphalt pavement were those who had to pay for it. They desired to have it on account of its beneficial effect on their property.

Mr. Wood said that it was claimed for the Nicholson pavement that it increased the value of property, but people thought differently when it had to be renewed.

Captain Torry said that a great deal of wood pavement was in use in London and Paris. In Paris a large amount of work has been done, and a man has made a contract to take care of the pavement for twenty years. Sometimes as high as a dollar persquare yard is paid. In London wooden pavements are put down and renewed as soon as they begin to be a little uneven. To keep asphalt pavement perfectly clean and in good repair for ever would cost about 40 cents per foot of property. On an average street in Cleveland it should cost a man who lives on a 40 foot lot about \$16 per year.

Mr. Morse said that if all the streets in the city were paved and were all paid for out of the general fund it would be well, but the pavement was a tax on the adjoining property.

Mr. Strong said that he would guarantee the pavement on Willson avenue for fifty years. Any depressions there have been caused by the taking up of sewers, etc.

Captain Torry said that there was no such trouble with asphalt. It could be taken up and relaid so that there would be no mark on the street. Like a patch on plaster, it can be put on so that the place cannot be discovered.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 19, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad station, Boston, at 7.30 P. M., President FitzGerald in the chair. Forty-eight Members and nine visitors present.

The record of the last meeting was read and approved.

Messrs. Louville Curtis and William M. Scanlan were elected Members of the Society.

The following were proposed for membership :

Mr. Charles W. S. Seymour, of Hingham, Mass., recommended by M. M. Tidd and W. S. Brown, and Edgar P. Sellew, of Somerville, Mass., recommended by Sidney Smith and G. A. Kimball.

On motion of Mr. Howe, it was voted : That the Secretary be requested to acknowledge, in the name of the Society, its great appreciation of the many kind attentions received from the following parties on the occasion of the excursion to Providence and Newport.

The Old Colony Railroad Company and General Manager J. R. Kendrick, for transportation and special car; City Engineer Samuel M. Gray, of Providence, for the very interesting exhibition of the public works under his charge; Captain Joseph P. Cotton, of Newport, and City Engineer Henry A. Bentley, of Newport, for their untiring efforts to make the visit to Newport enjoyable; Colonel Henry W. Closson, Commandant at Fort Adams, and the other officers of the Fourth Artillery, U. S. Army; Commander C. F. Goodrich, U. S. Navy, Commandant Torpedo Station, and Commander F. L. Higginson, U. S. Navy, Commandant Training Station, and the other officers of those stations for their courtesy to us.

The President read a letter from Mr. Henry E. Waite, of West Newton, presenting to the Society a " Kosmic " clock, which he had caused to be hung on the wall of the Society's room. On motion of Mr. Clarke, the Secretary was directed to suitably acknowledge its acceptance.

The Secretary read a circular from the Board of Direction of the American Society of Civil Engineers, containing an offer to send the Transactions of that Society " to any subscriber at the rate \$10 per year, and to clubs of ten or more, when ordered through the secretary of an engineering or technical society or club, who will be responsible for the payment, at 25 per cent. discount." Members of this Society who desired to avail themselves of the offer were requested to communicate with the Secretary at once.

The committee appointed at the last meeting to consider the communications from the Engineers' Club of Kansas City and the Western Society of Engineers submitted the following report :

Boston, Sept. 19, 1888.

To the Boston Society of Civil Engineers :

The Committee to whom was referred the appended communications* from the Engineers' Club of Kansas City and from the Committee on Highway Bridges of the Western Society of Engineers, respectfully report as follows:

First, That your Committee is unanimously of the opinion that this Society

* See Proceedings of Engineers' Club of Kansas City, May, 1888, JOURNAL, page 183, and Proceedings of Western Society of Engineers, June, 1888, JOURNAL, page 225.

should proceed very cautiously in the matter of recommending any legislative action which would result in state inspection of highway bridges, as it does not yet appear certain that this method in itself would secure the building of proper structures.

Second, That we do not recommend that the Society take any action in reference to establishing rates for the professional services of civil engineers.

Third, While your Committee dissent as above stated from the methods of action proposed in the communications referred to, we recommend that this Society take appropriate action on the subject of the improvement of highway bridges and appoint a committee to consider and report what legislative or other action would be advisable, and to what extent it would be practicable to co-operate with other societies in this matter.

(Signed) { JOHN E. CHENEY,
D. H. ANDREWS,
EDWARD S. SHAW.

The report was accepted, and on motion of Mr. Brooks the same Committee was reappointed to carry out the recommendations of the report.

Prof. Dwight Porter then read a paper on the "Removal of Roof Water," which was discussed by Messrs. Cheney, Clarke, Knapp, Olmsted and Smith.

Mr. J. Pickering Putnam, Architect, of Boston, was then introduced, and read a paper on "House Drainage." The paper was discussed at length by Col. Geo. E. Waring, Jr., of Newport, and Messrs. Clarke, Knapp, McClintock, Noyes and Smith, of the Society.

[*Adjourned.*]

S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

SEPTEMBER 5, 1888:—The 250th meeting was held, Vice-President John W. Weston in the chair.

The minutes of the last meeting were read and approved.

Mr. Henry S. Maddock, proposed at last meeting, was elected to membership.

From the reports of the Secretary and Treasurer, the following financial exhibit is compiled: Receipts since last meeting, \$136.50; cash on hand, \$88.32; bills paid, \$202.90; bills unpaid, \$0; bills reported, \$30.

Mr. Weston, from the Committee upon Memoirs of Messrs. Baker and Latimer, submitted a report which was ordered printed. Committee discharged.

The Secretary was instructed to forward paper with discussions, upon Classification of Material in Railway Construction, for publication.

The report of Committee on Employment, as printed in Proceedings for July, was made the special order for the next meeting. It is desired that Members who cannot be present should send in any discussion or suggestion before that date.

Mr. Rossiter called attention to the desirability of a translucent profile paper, suitable for blue printing, and thought that great improvement could be made in the standard papers used by engineers so as to adapt them to such use. The question was discussed at some length, and the general utility of other scales than those furnished was suggested. The following Committee was appointed to consider and report: Messrs. Rossiter, Williams and Parkhurst.

The Secretary read a paper by Mr. Geo. Y. Wisner, upon "Levels of the Lakes as Affected by the Proposed Lake Michigan and Mississippi Water-Way," and a discussion by himself. The matter was discussed by Messrs. Williams, Artingstall, Weston and others. The paper was laid over until next meeting for further discussion, and the Secretary instructed to send out copies to members and others who wished to discuss the subject.

[*Adjourned.*]

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

SEPTEMBER 3, 1888 :—Pursuant to adjournment at the June meeting the first regular meeting of the Autumn sessions was held Sept. 3, Vice-President Morri-son in the chair ; 12 Members, one visitor present.

Routine of business having been disposed of the resignation of C. L. Annan as Treasurer was accepted, and F. W. McCoy elected to the vacancy.

The papers of the evening were : first, one by F. W. McCoy upon Street Im-provements in St. Paul, giving a résumé of the amount, cost, and variety of dif-ferent street improvements in St. Paul during the past two years ; second, Mr. J. D. Estabrook, Superintendent of Parks in St. Paul, followed with an interesting paper upon the Changes of Level in the Northwestern Lakes. Illustrated by maps and charts, giving the variations in the Great Lakes and others, together with com-parisons with the rainfall for the last 25 years, a subject of special local impor-tance in reference to Lake Como.

After discussion of the papers the meeting adjourned.

GEORGE L. WILSON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

SEPTEMBER 3, 1888:—A regular meeting was held in Rooms 308 and 309, Baird Building, at 7:45 P. M. Mr. T. F. Wynne in the chair. Those present were Messrs. Wynne, Jenkins, Connett, F. W. Tuttle, F. B. Tuttle, Breithaupt, Bontecou, Florence, Taylor, Witmer, Hastings, Mason, Wells, Nier, Burton, K. Allen and nine visitors.

On a canvas of ballots—Messrs. Bontecou and Mason acting as tellers—Walton Clark and Edmund Sexton were elected Members.

After a description of a new cable railroad grip by Mr. Harris, the patentee, the Secretary read the minutes of the previous regular meeting. The Executive Committee had held three meetings, but had decided to defer engaging a new club-room until after the September meeting.

A communication from Mr. John F. Wallace was read entitled, "A Note on Flood Waves of the Missouri River," which was discussed by Mr. Nier.

A letter from Mr. B. W. De Courcy was read referring to Shrinkage in Em-bankments, and was discussed by Messrs. Burton, Nier, Bontecou and Mason.

The following were presented for the Club Library:

Proceedings American Society Civil Engineers, December, 1887, January and February, 1888; Proceedings National Association of Builders, 1888, with Stan-dard Specifications for Architects; Proceedings Engineers' Club of Philadelphia, February, 1888, with Supplement; Proceedings Indiana Society Civil Engineers and Surveyors, 1888; Report Newton (Mass.) Water Board, 1888; Constitution and By-Laws Montana Society Civil Engineers.

[Adjourned.]

KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

AUGUST 18, 1888 :—The regular monthly meeting was held at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Railway, at 7:30 P. M. In the absence of the President and Vice-Presidents, Mr. J. H. Farmer was elected Chair-man.

The minutes of the previous meeting were read and approved.

The Secretary reported having mailed to each member of the Society on July 26 last, a circular relative to reform in highway bridges, as proposed in the re-port of the Committee on Highway Bridges of the Western Society of Engineers,

requesting the views of members upon the same; he submitted the replies received all being "Aye" to the three questions as put by said Committee.

Among the replies received was one from Col. J. T. Dodge, past President, in which he says :

" 1st. In respect to the appointment of State Engineers.

" Were we to look for a precedent for the assumption of authority by the State to appoint an engineer whose approval must be obtained before any important highway bridge can be lawfully constructed, we should find that the State has taken supervision of many matters where private interests would otherwise be especially liable to suffer. It has appointed bank inspectors who are authorized to see that the business of banks is conducted in accordance with law. It appoints insurance commissioners to supervise and license insurance companies—without that supervision the insured would be entirely at the mercy of officers who held everything in their own hands. It only allows those to practice medicine who have received a commission from a legally established medical college. No lawyer can practice till he has been duly examined and admitted to the bar. Cities assume control of private building on the ground of public safety. They appoint building inspectors, to whom all plans of buildings must be submitted, and without his approval no work can be commenced. Cities also take charge of sewerage by means of an engineer. It is unnecessary to suggest to a society of engineers the absurdity of attempting that work by means of a boss mason and a gang of laborers.

" Now, there is no place where the public is more exposed to danger than in crossing a bridge; there is no work where expert knowledge is more requisite, none where the average man is less qualified to judge of the merits of a piece of work. Every reason which justifies governmental control or regulation of any of the matters above stated applies with equal or greater force to the proposed supervision of highway bridges. * * *

The subject was discussed at considerable length by the meeting, the tenor of all remarks being in full accord with those expressed by Colonel Dodge.

The question as to extending the duties of a State Engineer as proposed, to the inspection of railroad bridges, was discussed; some holding that while with irresponsible or careless companies it might prove beneficial to the public, it would be a doubtful policy to inspect the bridges of a responsible company, for in case of the failure of a bridge of such a company, it might be legally held that as the State had passed the bridge through its official examiner, it should be held responsible. It was also suggested in this connection that responsible companies always secured at least as high talent at the head of their engineering departments as it could be expected the State would obtain, for the engineer, while in the service of the State would, to a large extent, be remunerated by the honor of the position, and the intense satisfaction afforded through the opportunity presented of serving the public, as is manifested in a large number of positions of public trust.

A vote being taken upon the three questions submitted by the Committee of the Western Society of Engineers, resulted in a unanimous "aye" to all. The appointment of a committee to co-operate with that Society was placed in the order of special business for the next meeting.

A circular was read from Mr. John Bogart, Secretary of Am. S. C. E., relative to the *Transactions* of that Society being open for the publication of professional papers to other than members of that Society; also that the *Transactions* were open to public subscription. The Secretary was authorized to subscribe for said *Transactions* in the name of the Society for the current year.

Mr. Geo. O. Foss read a communication to the Society reciting the difficulties encountered in endeavoring to define the locus of mineral locations from an examination of records in County Recorders' offices and suggested remedies. He recom-

mends the subject to the Society for discussion, and suggests that a memorial be prepared and submitted to the next Legislature praying for the enactment of laws looking to the overcoming of annoyances experienced, not alone in defining the locus and boundaries of locations, but also their ownership. The subject was discussed and the communication filed with the Secretary for reading and discussion at the next meeting.

After an hour spent in informal discussion of various engineering subjects, the meeting adjourned to meet at same time and place September, 15, 1888.

J. S. KEERL, Secretary,

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

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- Aluminum Alloys by the Heroult Process.** Describes the method of producing aluminum alloys; also gives a table showing tensile strength and elongation obtained from a series of test made at Zurich. *Engr. News*, Sept. 8, 1888.
- Arches, Arched Ribs and Voussoir.** By H. M. Martin, before a students' meeting of the Institution of Civil Engineers. Gives a mathematical discussion of arched ribs and voussoir arches. *Proc. Inst. C. E.*, Vol. XCIII., pp. 462-477.
- Boiler, Efficiency of a, Using Waste Gas as Fuel.** By D. S. Jacobus, before the Birmingham meeting of the American Institute of Mining Engineers. Gives the results of trials made to determine the efficiency of a water-tube boiler with waste gas from a blast furnace as fuel. *Am. Engr.*, Aug. 15, 1888.
- Bridge, Brunswick, Eng.** Gives two-paged plate showing elevation and details of a hinged-arch foot bridge, spans 79 ft., over the River Oker at Brunswick, England. *Engineering*, Aug. 17, 1888.
- , *Hawkesbury, New South Wales.* Illustrations and description of the method of erecting on pontoons and floating to place. *R. R. Gazette*, Aug. 10, 1888.
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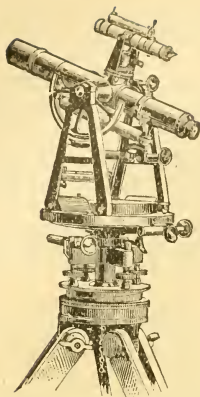
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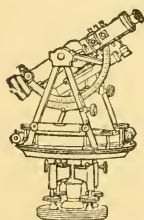
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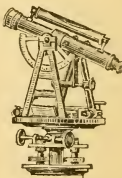
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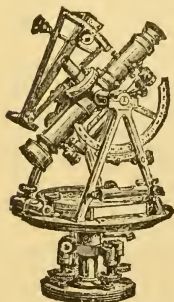
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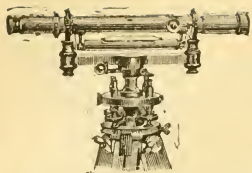
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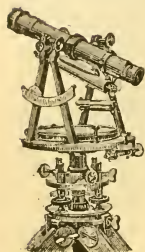
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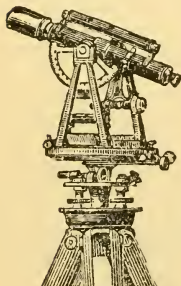
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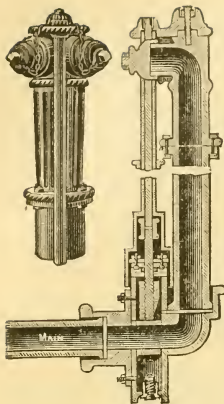
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THE TRANSMISSION OF POWER BY BELTING.

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[Read March 7, 1888.]

Belts and pulleys have been for some thirty years our most common means of transmitting power. Hundreds of thousands of dollars are consumed annually by the wear and destruction of belts, while not infrequently as much power is wasted in transmission as remains to be usefully applied. A good deal has been written upon belt transmission that is now of extremely little value ; because, until within a very few years, no accurate knowledge of the subject has existed ; and as yet, so far as I am aware, but little has been done to systematize our lately acquired knowledge.

The rules in common use in machine shops and by belt manufacturers to determine the size of belt required to transmit a given power are mostly taken from handy books of reference, and differ enormously from each other. To illustrate this, I have calculated by several such rules the width of a leather dynamo belt $\frac{3}{16}$ of an inch thick, which is to transmit 60 horse-power to a 16 inch iron pulley making 900 revolutions per minute. According to Nystrom's Mechanics, this belt should be 10 inches wide ; Haswell's Engineer's Pocket-Book gives 17 inches ; while the rules published in the recent catalogues of two prominent belt manufacturing concerns would make it respectively 46 inches and 48 inches. Supposing the belt to be 50 feet long, the difference in cost between the 10 inch and the 48 inch belt would be, at present prices, something over one hundred and fifty dollars. In practice, a 16 inch single belt, or an 8 inch double belt, does this work well. Examples might easily be selected that would show a wider disagreement than exists in the case just cited. Many of the rules in use are little better than guesses ; others are based upon experiment ; but even between these the differences amount in some cases to 100 per cent.

The chief aim of this paper is to bring together the most important results of some of the recent experiments upon belting, and to reduce them to such a form as may be readily and safely applied in practice.

The most important practical questions to be answered are :

First. What are the best materials, among those now in use, for belts, and for the pulley surfaces on which they run ?

Second. With given materials, what are the dimensions of belt and pulleys which will transmit the required power with greatest economy?

Third. Having determined upon the material and dimensions of the belt, how tight should it be stretched over the pulleys, and how are we to measure the tension put upon it?

Fourth. How do the different methods of joining the ends of the belt affect its efficiency, and what is the best way to make the joint?

The subjects of round belts, cords, link belts, and wire cables will not be included in this paper, which will be limited to the discussion of the transmission of power by flat belts of flexible material.

Of the materials in use for belts, the most common is leather; next follows rubber, (or, more exactly, cotton covered with vulcanized rubber); then comes cotton. This is generally in the form of a strong webbing or ducking, and is usually treated with a preserving coat to protect it from the action of the atmosphere and moisture. One type of cotton belt that does good service on harvesting machinery and in similar exposed situations, is made of several layers of strong duck, folded so as to bring the edges on the inside, and stitched together while under tension. The duck is soaked in oil and protected by what appears to be a thick, soft, red paint. The so-called "cotton-leather" belting is a comparatively new material. It is a woven cotton belt, with a thin facing of split leather glued upon one side to make a good surface to run upon the pulley. The number of stripes woven into it indicates the number of plies, or thicknesses, of the cotton, which is the strength-giving material of the belt. A good many belts of this kind are now in use, both for heavy and light service; and where protected from water, oil, etc., are doing excellent work. It is made by the Underwood Manufacturing Company, of Tolland, Conn.

For making rubber belting, a heavy duck of about 200 pounds tensile strength per inch of width is impregnated and coated on each side with a preparation of rubber, which is pressed against it between heavy rollers. Thus treated, the duck is cut into strips of the requisite width, folded, and pressed together by powerful heated rollers, making a belt of any required number of plies, three and four ply being the most common thicknesses. The long lengths of belting pass from the machine into the vulcanizing heater, where the process is completed. One firm of belt manufacturers still further unites the plies of the belt by longitudinal rows of cotton cord stays or flexible rivets, driven through the belt. These cords are cut to project about a quarter of an inch on each side of the belt, and are then imbedded in the rubber coating of the duck under pressure; the outer covering is then applied, and the whole vulcanized together. These belts, when well made, do very satisfactory work, and are especially adapted to use in damp places, or where they are exposed to the action of the weather.

Oak tanned leather, which was the material first placed on the market for this purpose, still holds its place at the head of belting materials. The hides of young steers are generally selected for belt leather, and only about 36 inches in width of the central portion of the hide should be used. After being soaked in lime water, unhaired and scraped, the extractive matter of the skin being dissolved out, leaving only the fibres

with some gelatinous matter, the hides are put to soak in a watery solution of tannic acid, where they should remain six or seven months. The duration of this process varies with different makers. A process lasting two years is said to make better leather, but the increased value is not generally thought sufficient to warrant the greater expense of manufacture. Various materials are sometimes used for making the tan liquor, but for belt leather, there is nothing known which answers so well as ground oak bark. After the tanning process, the hide is thoroughly washed by the currier, and after being allowed to get partially dry, is greased with tallow and cod oil, and hung up. As the moisture goes out, the oleine of the dressing penetrates the leather by capillary attraction, leaving most of the solid part, or stearine, to be scraped off from the outside. The oil which has penetrated the leather rapidly oxidizes, forming an elastic, gummy substance, which coats each fibre and binds them all together. The mechanical processes of currying and finishing also serve to compact the fibres, and the result is a great increase in strength and elasticity over the uncurried tanned leather. The leather thus prepared is cut into strips of the proper width for making belts, and "the stretch taken out of it" by suitable machines. Usually a single ply or thickness of leather is used for the narrow widths, two-ply for wider, and three or four for the very wide. These different thicknesses are scarf jointed at the ends, and put together with a cement made of a mixture of fish glue and ordinary glue under heavy pressure, breaking joint over the various unions when more than one thickness is used, so as to make a smooth, even band. Copper rivets, shoe pegs, stitching, and wire sewing or riveting are methods used to supplement the holding power of the glue, but these aids are unnecessary if the belts can be protected from water and machine oil when in use.

The flesh side of leather possesses much greater tensile strength than the grain, or hair side, the part having the greatest strength being about one-third of the way through from the flesh side. On this account chiefly it is better to run the hair side of a single ply belt next to the pulley, placing the strength-giving part on the outside, where it is exposed to the greatest tension, and where it is also protected from wear. Double belts generally have the two flesh sides put together in the middle, and may run either side to the pulley.

The Shultz patent fullered leather differs from ordinary oak tanned leather chiefly in being left for a shorter time in the tan vats, so that it is fully tanned only on the surface, the inside being in a condition approaching that of rawhide. It is afterward subjected to a mechanical working over in a special machine, which makes it softer and more pliable than ordinary belt leather. Rawhide belting is even more pliable and elastic than Shultz leather. Rawhide is also an excellent material for belt lacings.

The cost of good leather or rawhide belting is at present from sixty cents to one dollar per square foot for single thickness, the wider belts being the more expensive. Three-ply rubber belting, which is about equivalent to leather of single thickness, costs about three-fourths as much per square foot. Cotton belting costs about half as much as leather.

Various other materials besides those mentioned have been and are occasionally used for belts, including among others gutta percha, wool, intestines, and paper. Even sheet iron has been successfully used for heavy work at slow speed.

Belts generally drive and are driven by friction, and their driving power, therefore, depends partly upon the *co-efficient of friction*; that is, upon the *ratio* which the *force required to slip the belt* over any part of the pulley circumference bears to the *normal pressure of the belt on the pulley* at the same point. The force which tends to slip the belt over the surface of the pulley, or the effective force exerted by the belt to turn the pulley, is the difference between the forward pull of the tight or driving side of the belt and the backward pull of the slack or following side. Now, assuming the co-efficient of friction to be uniform all around the arc of contact of the belt on the pulley, it can be proved that, where T_1 represents the tension on the tight side of the belt, and T_2 the smaller tension on the slack side, then the co-efficient of friction is given by the equation

$$f = \frac{0.37}{A} \log. \frac{T_1}{T_2}$$

where A is the fraction of the pulley circumference inwrapped by the belt. The demonstration of this formula, or a formula equivalent to this, may be found in any book on applied mechanics, and as its mathematical accuracy is not questioned, I will not take the time here to demonstrate it. From this formula it is evident that if we can find the ratio of the two tensions required to slip the belt over the pulley at any desired speed, we can calculate the value of the co-efficient of friction corresponding to that speed of slip.

A great many experiments have been made to determine the value of f , especially for a leather belt running upon a turned cast iron pulley. Among the most noteworthy of the earlier experiments are those made by Gen. Morin, by Henry R. Towne, of the Yale & Towne Manufacturing Company, Stamford, Conn., by Edward Sawyer, of Charlestown, Mass., and by J. Howard Cromwell, of New York. All these gentlemen used the same general method, and seem to have performed their work with great care. A piece of belt was hung over a fixed iron pulley, or drum, and loaded at its ends with equal weights; then more weight was added on one side until the belt slipped. The ratio of the two weights was then taken as corresponding to the ratio $\frac{T_1}{T_2}$ in the formula for the co-efficient of friction. The different values of f obtained by these experimenters are here tabulated, the results being arranged in the order in which the experiments were made.

Experimenter.	Co-eff. of friction for leather belt on iron pulley.
Gen. Morin.....	$f = 0.28$
Henry R. Towne.....	$f = 0.58$
Edward Sawyer.....	$f = 0.12$ to 0.17
J. Howard Cromwell.....	$f = 0.40$

These results are sufficiently various to justify a belief that some important factor which effects the co-efficient of friction has been over-

looked. A little reasoning on the subject will suggest a possible cause for this variation. The theory of belts that has been generally accepted until recently, assumes that the co-efficient of friction of a belt on a pulley follows the same law as is approximately true for friction between metal surfaces, viz., that the co-efficient is independent of the pressure and of the velocity of sliding. Suppose that we have a motor driving a machine, for example a fan, by means of a belt, the pulleys being of equal size. If we apply a revolution-counter to each shaft, we generally find that the speed of the driven pulley is one or two per cent. less than the speed of the driver, showing that the belt slips to some extent on the surface of the pulleys. Now if we increase the speed of the motor under this condition of things, we shall increase also the speed of the fan; but as the resistance to the motion of the fan is greater at higher speed, in order to accomplish this result the force applied to the pulley by the friction of the belt must increase also. It is also found that the belt slips more under the greater load than it did before. In other words, an increase of friction is accompanied by an increased speed of slip, which renders it probable that the ordinary laws of friction for metal surfaces do not apply to belts, and that the co-efficient of friction of a belt on a pulley increases with its speed of slip. Though these were matters of common experience, no one seems to have suspected their importance until a few years ago.

In 1882, Prof. S. W. Holman, of the Massachusetts Institute of Technology, undertook a set of experiments to determine how much the co-efficient of friction of a belt on a pulley is affected by the speed of slip, and whether the variation from that cause is sufficient to explain the enormous discrepancies in the results obtained by the earlier experimenters. The principal part of his apparatus was a pulley mounted so that it could be turned at various definite and rather slow speeds. Over this pulley was hung a piece of belt, a weight hung upon one end constituting the load on the tight side, while the load on the slack side was measured by a spring balance. The pulley being turned at a known speed in the direction tending to raise the weight, the effect is to reduce the tension on the spring balance below that corresponding to the weight by just the amount of the friction corresponding to the speed with which the surface of the pulley slides under the belt. By determining in this way the values of T_1 and T_2 at a series of different speeds, and substituting them in the formula already given, we can find the value of f corresponding to any desired speed of slip—the fraction of the circumference embraced by the belt, A , having the same value, one-half, in every case. Professor Holman wrote a brief paper describing his apparatus, and the results obtained with it, which may be found in the *Journal of the Franklin Institute* for September, 1885.

He found that with a speed of slip of 50 feet per minute the value of f was about 0.58, and with a very low speed of slip he obtained a small value as 0.12, while for intermediate speeds he obtained values between these two.

These experiments finally settled the question of the variation of the co-efficient of friction with the speed of slip of the belt; and as Prof.

Holman has pointed out, the introduction of this factor of speed of slip goes a good way towards accounting for the various results obtained by previous experimenters. Gen. Morin in his experiments loaded one side until the belt slipped, but does not tell us how fast it was slipping. Mr. Edward Sawyer, after loading the heavy side enough to make the belt slip, added weight on the light side until he just stopped the slipping, which accounts for his small value of the co-efficient (0.12), corresponding to the slowest speed of slip used in Prof. Holman's experiments. An account of his work may be found in the *Proceedings of the Society of Arts of the Mass. Institute of Technology* for 1881-2. Mr. Henry R. Towne, whose experiments are described in the *Journal of the Franklin Institute* for 1868, and who obtained the highest value for f , says that he allowed his belts to slip as near 200 feet per minute as he could judge by the eye. Mr. Cromwell, whose experiments are described in his recent book on belting, seems to have made no measurements upon speed of slip.

Evidently no theory of belting can be accepted which neglects this very important consideration of the speed of slip, and before we can make a rational formula for calculating the power which a belt can transmit, or the size of belt required to transmit a given power, we must first decide upon how much we are willing that the belt should slip on the pulley.

That we cannot transmit power in this way without *some slip*, may be proved by trial, or theoretically thus :

Let A and B (Fig. 1) represent a pair of pulleys connected by a belt. Suppose the pulleys are at rest, and the tensions on the two halves of the belt equal; then, in the case of a horizontal belt, the two sides sag equally, as represented by the lines c and f . Suppose we now mark a series of points along the edge of the belt exactly one foot apart. Now if the pulley A rotates and drives B , the tension on the lower, or driving, side of the belt will become greater than it was before, and that on the upper side will be less than before, so that the two sides of the belt will now be represented by the lines d and e . As a belt stretches under tension, and contracts when that tension is removed, the points on the tight side of the belt are now more than one foot apart, and those on the slack side are less than one foot apart. Now as the pulley B revolves, the number of points which pass on to the rim of the pulley in a given time must be just equal to the number which pass off it in the same time; that is, the number of divisions which pass the points h and k in the same time are equal; but as, on account of the difference in tension, the divisions passing k are each longer than the divisions passing h , the velocity with which the belt leaves the pulley at k is greater than the velocity with which it runs on at h ; and the velocity of the belt increases constantly as it passes around the pulley B from h to k , the points in advance moving farther away from those in the rear, as the belt stretches under the increasing tension. In passing around the pulley A the reverse action takes place, the points in advance falling back so as to shorten the spaces, as the tension is reduced. As the velocity of the belt on each pulley varies at different parts of the circumference, while the velocity of the pulley itself is the same at all points of the surface, it follows that a belt made of any stretchable ma-

terial must always slip on the pulleys whenever the tension on the two sides is different; that is, whenever the belt is transmitting any power. This effect is called the *creep* of the belt. It always creeps backward on the driving pulley and forward on the driven pulley, so that the effect is to make the surface speed of the driven pulley fall behind that of the driver by a certain proportion, corresponding to the per cent. which the belt stretches in passing from the tension T_2 to the tension T_1 . The loss due to this creeping effect, in the case of a leather belt under ordinary conditions, probably amounts to about $\frac{1}{2}$ of one per cent., or $\frac{1}{4}$ of one per cent. on each pulley, and cannot be reduced by tightening the belt. It can be reduced only by using a wider or thicker belt, or one that will stretch less under the required difference in tension. In addition to this effect there is frequently more or less true slip.

Some experiments have been made to determine what average speed of slip of belt on pulley is proper to allow. It has been determined that when the average speed of slip rises as high as 10 per cent. of the belt speed, the belt will generally fly off the pulley. Of course this limit should not usually be approached in practice, but a knowledge of it may be useful in determining the allowable fluctuations of speed in such tools

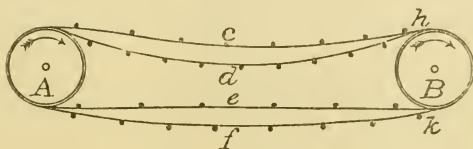


Figure 1.

as punching machines. Experiments made at the Massachusetts Institute of Technology in 1884 and 1885, under the direction of Prof. Lanza, indicate that the average speed of slip of a leather belt on an iron pulley should not exceed about $\frac{3}{10}$ of one per cent. of the belt speed. This would make the surface speed of the driven pulley fall behind that of the driver about $\frac{3}{10}$ of one per cent., which agrees with the practice in some first-class electric light stations and mills. In developing my formula for belts, I have therefore allowed a speed of slip of the belt on the pulley equal to $\frac{3}{10}$ of one per cent. of the belt speed. A larger allowance would simply change the constants of the equation, without altering its form, provided a *fixed proportion* is kept between slip and belt speed.

It is quite probable that the coefficient of friction of a belt on a pulley varies with the pressure, as well as with the speed of slip. From an elaborate series of experiments made by William Sellers & Co., of Philadelphia, and described in a paper by Mr. Wilfred Lewis in the *Transactions of the American Society of Mechanical Engineers* for 1886, Mr. Lewis thinks it probable that the co-efficient of friction generally increases as the pressure per square inch is reduced, a law which, if true, would be in favor of using large pulleys. As this relation is not proved, and is, indeed, contradicted by the results of some other experiments, and as its effect is evidently not so important as that of the speed of slip, I have here made no attempt to take it into account. The co-efficient of friction of leather

belts on pulleys is also known to vary to a very great extent with the condition of the surfaces, the amount of belt dressing used, and somewhat with temperature and the condition of the atmosphere. These causes of variation, however, come under the head of accidental causes, which should not properly be taken into account in a general formula for the width of a belt, which should make the width sufficient to do the work under the most unfavorable conditions liable to occur in ordinary practice.

There is need of further careful experiment to determine definitely if possible the relations of the co-efficient of friction both to speed of slip and to pressure. There is not yet enough knowledge of the subject to enable us to make an exact formula for calculating either the co-efficient of friction or the dimensions of a belt. What I have attempted to do, therefore, is to make as close an approximation to an exact formula as the condition of our knowledge will allow, and then to find the simplest expression which will represent it with sufficient accuracy for use.

I have first attempted, in the case of a leather belt on an iron pulley, (which is the only case for which there are sufficient experimental data), to establish some simple relation between the co-efficient of friction and the speed of slip. To do this I have collected the results of all the experiments I know of where the co-efficient of friction of a common leather belt on a smooth iron pulley, and also the corresponding speed of slip, have been measured, and have plotted them on paper, making abscissas represent speeds of slip and ordinates the corresponding values of the co-efficient of friction. Mr. Holman's experiments have been most useful, being directed especially to the determination of this point, and besides them I have included the results of some experiments by Henry R. Towne, by Professor Lanza, by William Sellers & Co., and of a few experiments made by last year's class in the Department of Dynamic Engineering at Washington University.

As might have been expected, considering the great variations that may be produced by what I have called accidental causes, the plotted points were so scattered that it was impossible to draw a curve that would even approximately represent them all; but it was found possible to draw a smooth curve bounding the lower side of the area occupied by the plotted points, and representing, therefore, the probable *minimum value* of the co-efficient of friction for each speed of slip. The experiments covered a range of speeds of slip from 2 inches to 200 feet per minute. Now, as a formula for calculating the width of a belt should make it sufficient to do its work well with the lowest value which the co-efficient of friction is liable to have under ordinary conditions, it appears that what is wanted for this purpose is the minimum, rather than the average, value of the co-efficient.

The curve thus obtained was convex on the upper side, rising almost vertically at first, and becoming nearly horizontal for speeds of slip above 50 feet per minute. Its equation, as determined by the well-known logarithmic method, is, approximately, $f = .207 V^{-\frac{1}{4}}$, where f is the co-efficient of friction and V is the velocity of sliding in feet per minute. That is to say, that as nearly as can be determined from experiments already made, it is safe to assume, for calculations within the limits of

ordinary practice, that the co-efficient of friction of a leather belt on an iron pulley varies approximately as the fourth root of the speed of slip; and that under ordinary conditions its value will not fall below that given by the formula just stated.

A good many experiments on the co-efficient of friction of belting have been made at a speed of slip of about 3 feet per minute: and it will be convenient to introduce into our expression for the co-efficient of friction a constant term corresponding to the value of the co-efficient at that speed. The mean value obtained by Prof. Holman at that speed, which result has been since confirmed by the experiments of Professor Lanza, was 0.27, which agrees very well with the value given by our formula. If we represent the co-efficient of friction at a speed of slip of 3 feet per minute by f' , and by f the value of the co-efficient at a velocity of slip V' , we may write

$$f = \frac{.207}{.27} f' V'^{\frac{1}{4}}.$$

(As $f' = .27$, the value of this expression is the same as that of the preceding one.)

Now as the co-efficient of friction varies with the speed of slip (which includes also the creep of the belt), and as the speed of creep, as well as the normal pressure, varies on different parts of the arc of the pulley embraced by the belt, it is evident that when a belt is running under the conditions of practice, the co-efficient of friction *will not be uniform* throughout the arc of contact, as is assumed in the derivation of the ordinary logarithmic formula; and moreover, it will vary in a different way on the driven pulley from what it does on the driving pulley: because in the one case the velocity of sliding, and with it the co-efficient of friction *increases* as we go from the slack to the tight side around the arc of contact, and in the other case it decreases. The effect of the creep in varying the velocity of sliding at different parts of the arc of contact of a leather belt on an iron pulley must be frequently sufficient to cause the co-efficient of friction to vary three or fourfold at different parts of the circumference. The smaller the per cent. of true slip of the belt the greater would be this variation. Evidently then, the formula

$$f = \frac{0.37 \log \frac{T_1}{T_2}}{A}, \text{ which can be derived only on the assumption of a uni-}$$

form co-efficient, is not applicable to the general case of a belt transmitting power from one pulley to another.

However, neglecting the probably small variation in the co-efficient due to varying pressure, this formula is perfectly applicable to experiments like those of Mr. Holman; for where the belt stands still and the pulley turns under it, the velocity of sliding is the same at all points, and the value of f , as found in the ordinary way, is the true value of the co-efficient of friction corresponding to that speed of slip. This formula also gives the value of the co-efficient in experiments like those of Morin, —who, I believe, was the first to apply it,—that is, in cases where the belt is made to slide over a fixed drum.

Applying it, therefore, to such cases, we may place our two values of f equal to each other, and write

$$\frac{0.37 \log \frac{T_1}{T_2}}{A} = \frac{.207}{.27} f' V^{\frac{1}{4}} \quad \text{or,} \quad \log \frac{T_1}{T_2} = 2.08 A f' V^{\frac{1}{4}} \quad (1)$$

This formula, as we have seen, does not apply to the general case of a running belt; but for the special purpose of *calculating the proper width of a belt* to transmit a given power, the conditions are generally such that an equation of this form may still be used, as we will proceed to prove.

The necessary conditions are that the mean speed of slip V' shall bear a fixed ratio to the belt speed V , and the belt shall be strained to its maximum safe-working tension on the tight side. Under the latter condition, the true *creep* of the belt will also be nearly proportional to the belt speed; and with the usual arc of contact of about one-half the circumference, the variation in the velocity of slip at different parts of the arc of contact will follow approximately the same law at all speeds of belt. That is to say, that while the co-efficient of friction will vary at different points on the arc of contact of every pulley according to some function of the angular distance θ from the slack side, under the above conditions it will vary according to nearly the *same* function of θ at all speeds of belt. Also, for different belt speeds, the co-efficient of friction on each element of the arc of contact will vary proportionally to $V'^{\frac{1}{4}}$, where V' is the mean velocity of slip. Therefore the general value for the co-efficient of friction for any point of the arc of contact whose angular distance is θ from the slack end, and for any mean speed of slip V' , may be written thus:

$$f = C V'^{\frac{1}{4}} F(\theta),$$

θ and V' being independent variables, and C a constant. Now let $d T$ be the difference in tension at the two ends of the elementary arc $d \theta$, and T the tension which draws the belt against the pulley at that point; now it may be easily proved that the pressure on the elementary arc is equal to $T d \theta$; and the frictional force exerted by the belt on the elementary arc of the pulley is therefore $d T = f T d \theta$. Substituting for f its value,

and transposing, we have $\frac{d T}{T} = C V'^{\frac{1}{4}} F(\theta) d \theta$, or

$$\int_{T_2}^{T_1} \frac{d T}{T} = C V'^{\frac{1}{4}} \int_0^{\theta} F(\theta) d \theta, \quad (2)$$

$$\text{or} \quad \log \frac{T_1}{T_2} = C V'^{\frac{1}{4}} F'(\theta) \quad (3)$$

Now if the co-efficient of friction were *uniform* around the arc of contact, $F(\theta)$ in equation (2) would be unity, (or θ to the 0 power), and $F'(\theta)$, in equation (3) would therefore be simply the first power of θ ; but as f *increases* with θ on the driven pulley, for that case $F(\theta)$ would be some direct or positive function, and $F'(\theta)$ would be some function higher than the first power. On the other hand, for the driving pulley f *decreases* as θ increases, or $F(\theta)$ is an inverse function, making $F'(\theta)$ a function lower than the first power. However, as the arc of contact varies but slightly in ordinary practice, it will not be worth while to take this difference into

account and use separate formulas for driving and driven pulleys. The best way will be to take a function of θ intermediate between the two unknown functions applying respectively to driving and driven pulleys; that is, to use the first power of θ , which will make our equation read :

$$\log \frac{T_1}{T_2} = C V^{\frac{1}{4}} \theta,$$

where T_1 and T_2 are the forces exerted respectively by the tight and slack sides of the belt to draw it against the pulley, θ is the arc of contact in angular measure, and V is the mean velocity of slip allowed. As it is more convenient for general use to express the arc of contact as a fraction of the whole circumference, which we have before represented by A , we may substitute for θ in this expression its value in terms of A , changing the constant from C to C' . We have then

$$\log \frac{T_1}{T_2} = C' V^{\frac{1}{4}} A,$$

an equation which becomes identical with equation (1) when we substitute $2.08 f'$ as the value of C' , which is thus determined. We then have, as an equation for use in determining the dimensions of a belt,

$$\log \frac{T_1}{T_2} = 2.08 A f' V^{\frac{1}{4}}.$$

Now, as the velocity of slip V should be a certain definite proportion, say $\frac{3}{100}$ of one per cent., of the belt speed V , we may still further transform this equation by substituting $.003 V$ for V' , which will reduce our constant to 0.5, making the equation read

$$\log \frac{T_1}{T_2} = 0.5 A f' V^{\frac{1}{4}},$$

where V is the belt speed in feet per minute. This means that for a fixed per cent. of slip the ratio of the two tensions $\frac{T_1}{T_2}$ would be the number corresponding to the logarithm $0.5 A f' V^{\frac{1}{4}}$, which is expressed symbolically thus :

$$\frac{T_1}{T_2} = \log_{-1} 0.5 A f' V^{\frac{1}{4}}.$$

This equation may be transformed so as to read

$$T_1 = (T_1 - T) \left\{ \frac{\log_{-1} 0.5 A f' \sqrt[4]{V}}{\log_{-1} 0.5 A f' \sqrt[4]{V} - 1} \right\} \quad (4)$$

Now, T_1 , or the force exerted on the pulley by the tight side of the belt, must not exceed a certain amount per inch of width, which the belt can safely withstand without excessive stretching. That is, if S' represents the available working tension of the belt in pounds per inch of width, and W is the width of the belt in inches, then

$$T_1 = WS'.$$

Now, when a belt passes around a pulley at high speed, a certain force is required to deviate the belt from a straight course, and make it move in an arc of a circle around the pulley, or, as commonly stated, a certain tension in the belt is needed to balance the centrifugal force; and this part of the tension is not available for producing adhesion to the pulley. Let w be the weight of a piece of belt one foot long and one inch wide,

and V as before the velocity of the belt; then the centrifugal tension per inch of width is equal to

$$\frac{87 w V^2}{10^7}.$$

Therefore, if we subtract this quantity from the working strength of the material per inch of width, we shall have left the working strength available for transmitting power; that is, if S represents the number of pounds tension per inch of width which the belt can safely and continuously withstand, then the available working tension,

$$S' = S - \frac{87 w V^2}{10^7};$$

and, substituting this value in the last equation, we may put

$$T_1 = W \left(S - \frac{87 w V^2}{10^7} \right).$$

Referring again to equation (4), the term $T_1 - T_2$ in the second member of the equation, or the difference between the forces exerted on the pulley by the two sides of the belt, represents the effective force transmitted, which is equal to the work done per minute in foot pounds divided by the distance traversed by the belt in feet in the same time. Or if HP represent the number of horse power transmitted by the belt,

$$T_1 - T_2 = \frac{33,000 HP}{V}.$$

Substituting, now, in equation (4) the values we have found for T_1 and $T_1 - T_2$, we obtain an equation from which we can find the proper width of belt to transmit any required horse power, without exceeding the assumed per cent. of slip, viz. :

$$W = \left\{ \frac{\left(\frac{33,000 HP}{V} \right) \left(\frac{\log_{-1} 0.5 A f' \sqrt[4]{V}}{\left(\log_{-1} 0.5 A f' \sqrt[4]{V} \right) - 1} \right)}{S - \frac{87 w V^2}{10^7}} \right\} \quad (5)$$

In this equation,

W = width of belt in inches; HP = horse power transmitted;

V = speed of belt in feet per minute;

A = fraction of circumference inwrapped by belt;

f' = co-efficient of friction for a slip of 3 feet per minute;

S = safe working tension in pounds per inch of width;

w = weight in pounds of belt 1 foot long and 1 inch wide.

To apply this equation to other kinds of belt than leather and to other pulley surfaces than iron, we may substitute for w and S the proper values for the weight and safe working tension for the kind of belt in question, and for f' put the co-efficient of friction of the given surfaces at a speed of slip of 3 feet per minute; assuming, as our experiments so far indicate, that the law of variation of co-efficient of friction with speed of slip is approximately the same for each kind of belt.

I may here give the average weight of a foot of 1 inch belt $\frac{7}{8}$ inch thick for the various materials which I have tested. It will be seen that

the weights of the common materials do not differ very widely, rubber being the heaviest, and cotton the lightest.

	Lb.
Rubber.....	$w = 0.11$
Leather, best oak tanned.....	$w = 0.095$
Rawhide.....	$w = 0.091$
Shultz fulled leather.....	$w = 0.09$
Cotton leather.....	$w = 0.08$

These values are computed for a belt $\frac{7}{32}$ of an inch thick, which is about the ordinary thickness of a single leather belt. For other thicknesses the value should be proportionally greater or less. The *three-ply* rubber or cotton-leather belt corresponds in thickness to a single leather belt; that is, about $\frac{7}{32}$ inch. Rubber belts increase in thickness about $\frac{1}{16}$ of an inch for each ply, and the cotton-leather belts at the rate of about $\frac{8}{32}$ inch for two plies. Single Shultz belting is about $\frac{8}{32}$ inch thick, and rawhide about $\frac{5}{32}$ inch.

The safe working tension, or the greatest stress which a belt can continuously resist without undue stretching, depends upon the strength and elasticity of the material. In order to determine the relative strength of the different materials commonly used, a series of tests was made at the University last year by the students in dynamic engineering. The points investigated in these tests were the ultimate tensile or breaking strength, the elongation under a moderate fixed load, and the co-efficient of friction on a smooth cast-iron pulley. The tests were undertaken primarily to afford practice and instruction to the students, and make no pretensions to completeness, the number of specimens of each kind tested being too small to furnish close average values. The pieces used in the tests were all new, being supplied by the manufacturers for this purpose. The measurements of tensile strength and elongation were performed upon the Riehle testing machine in the laboratory of the University, the ordinary methods for tensile tests being used. A summary of the results is here given.

TENSILE STRENGTH AND EXTENSION OF VARIOUS KINDS OF BELTING. DEPARTMENT OF DYNAMIC ENGINEERING, WASHINGTON UNIVERSITY, ST. LOUIS, MAY, 1887.

Material.	Breaking stress in pounds per sq. in.			Extension at 400 pounds per sq. in.
	Minimum.	Maximum.	Average.	
Best oak leather.....	2,850	8,000	5,248	.018
Rawhide.....	3,000	6,754	4,889	.180
Shultz leather.....	2,990	5,666	4,618	.035
Rubber	2,913	3,888	3,360	.059
Cotton leather.....	2,969	3,714	3,465	.037

From the first two columns in the table it appears, as might be expected, that in each of the three forms of leather belt there is a wide variation in the strength of different specimens, while in the case of the rubber and cotton-leather belts there is much greater uniformity. The minimum figures for the five kinds of belting, however, do not differ

materially from each other. The relatively great extensibility of the rawhide belt is also noticeable. The extension tests, however, showed such great variations between different specimens of the same kind of belt, and the number of tests of each kind was so small, that these results cannot be considered as at all accurate measures of the relative extensibility. The time allowed for the stretch to take effect was merely that required to adjust the load and take the measurement, perhaps two or three minutes.

The inference drawn by the writer from these tests is that the tension that may safely be allowed in practice is about the same for all the above varieties of belting.

The percentage of the breaking load that a belt will bear and work satisfactorily can only be determined by experience in actual use. Most of the recent experimenters concur in recommending for a single leather belt a maximum tension on the tight side of about 66 pounds per inch in width, which would correspond to about 300 pounds per square inch, or one-tenth of the breaking load. The writer's experience with belts, both with those that have proved satisfactory and with some that have not, tends to sustain these figures. If it is admitted that the working strength per square inch of section is about the same for all the common kinds of belting, the selection of the best kind of belt to use in any case would therefore depend on other considerations, such as durability, cost, adhesion to pulley, and adaptability to the special conditions of the work. The belt of greatest driving power per inch of cross section would be that having the largest co-efficient of friction on the given pulley surface.

To determine the relative co-efficients of friction on cast iron at various speeds of slip, an apparatus on the principle of Prof. Holman's device was used, a small pulley being swung in a lathe so that it could be revolved at various speeds. The machine was rather crude, and no extreme degree of precision can be claimed for the results obtained with it. The strips of belt to be tested were hung over this pulley so as to embrace one-half its circumference, a weight hung upon one end constituting the load on the tight side, while the tension on the slack side was determined by a spring balance. The strips of belt used were each two inches wide and of a thickness corresponding to single leather belt, and were each subjected to exactly similar tests, the object being to determine the *relative* values of the co-efficient of friction for the different kinds, rather than to fix it absolutely for any one kind. With each piece of belt three different weights were used on the tight side, of 148, 104, and 51 pounds respectively, a set of observations being taken with each weight at various speeds of slip between one and sixty feet per minute. The pulley was rotated in the direction tending to raise the weight, the effect being to reduce the tension on the spring balance below that corresponding to the weight on the tight side, by just the amount of the friction. About thirty trials were made with each piece of belt at different speeds of slip, the latter being determined by counting the revolutions per minute of the pulley.

It was found that the force with which the belt is pressed against the pulley has a noticeable effect upon the co-efficient of friction, but the variation of the co-efficient with the pressure seemed to be irregular

and could not be reduced to any law, In every case the co-efficient of friction was found to increase rapidly with the speed of slip, the rate of increase being greater at low than at high speeds.

It is evident that in order to compare the co-efficients of friction of different kinds of belting we must place them under identical conditions as to pressure and speed of slip. In this case the comparisons were made at a speed of slip of three feet per minute, and with a load of 104 pounds on the tight side, these being selected as corresponding with the average conditions under which the belts would be used in practice. The relation between the average co-efficients for the different materials is shown by the following table, in which the co-efficient for oak tanned leather is called unity, no attempt being made to fix its absolute value.

Relative value of co-efficients of friction of various kinds of belting on iron pulley, as compared with leather.

Oak-tanned leather (hair side)	1 00
Cotton leather.....	1.15
Raw hide.....	1.17
Shultz fulled leather.....	1.30
Rubber.....	2.22

Taking 0.27 as the value of the co-efficient for leather on iron at a speed of slip of 3 feet per minute, this gives as the values of f' for the various kinds of belting the following :

Oak-tanned leather on iron, 3 feet per minute slip.....	$f' = 0.27$
Cotton leather on iron, 3 feet per minute slip.....	$f' = 0.31$
Raw hide on iron, 3 feet per minute slip.....	$f' = 0.32$
Shultz fulled leather on iron, 3 feet per minute slip	$f' = 0.35$
Rubber on iron, 3 feet per minute slip.....	$f' = 0.60$

These figures agree fairly well with the experiments that have been made at the Massachusetts Institute of Technology, except in the case of the rawhide belt, which their results would make about 0.41. The difference is, perhaps, due to a difference in the condition of the belt, that tested here being new and quite oily. We have as yet made no measurements of the co-efficient of friction upon lagged pulleys ; a few have been made, however, at the Massachusetts Institute of Technology, which, reduced to a speed of slip of 3 feet per minute, give for

Oak-tanned leather on a leather-lagged pulley.....	$f' = 0.5$
Rubber on a leather-lagged pulley.....	$f' = 0.7$

It is noticeable that the increase in the co-efficient for a lagged over an unlagged pulley is much greater for leather than for rubber, the co-efficient for leather being nearly doubled by lagging the pulley, while that of rubber is only slightly increased.

From the foregoing it would appear that, leaving out of account other considerations, (such as cost, durability, etc.), the best belt to run on a bare cast-iron pulley is a rubber belt. In case any other kind of belting is used, the pulley should be lagged, unless, for some special case, as a shifting belt, it is desirable not to have too great adhesion of the belt to the pulley.

The most complete of the modern experiments upon belting are those that have been made upon belts running under the conditions of practice. The first of this kind were made at the Massachusetts Institute of Technology under the direction of Professor Lanza in 1885, and a more extensive series was made at about the same time by William Sellers & Co..

at Philadelphia. Both sets of experiments, with the results, are described in the *Transactions of the American Society of Mechanical Engineers* for 1886. The principle of the method used in each case was to suspend the driving shaft on a scale in such a way that the pull of the belt upon it could be weighed, giving the sum of the tension on the two sides, or $T_1 + T_2$; while a Prony brake on the driven shaft measured the force transmitted, giving the difference of the tensions on the tight and slack sides, or $T_1 - T_2$, from which two determinations the values of T_1 and T_2 can be easily calculated. A revolution counter was attached to each shaft, the difference in the numbers of revolutions in a given time determining the mean speed of slip.

These experiments have brought out a great many interesting facts, prominent among which is the fact that the sum of the two tensions, $T_1 + T_2$, does not remain constant under different loads, as has been assumed in the old theory of belting, (on the supposition that the stress is proportional to the strain), but that it increases with the load to the maximum extent of about 33 per cent. with vertical belts, its increase varying somewhat with the co-efficient of friction; and that in the case of a horizontal belt, where the tension on the slack side may be kept up by the weight of the belt, the sum of the tensions may increase indefinitely, as far as the breaking strength of the material. This fact should be considered in determining how tight a belt should be first stretched over the pulleys, in order to get the proper tension when running.

The formula for calculating the width of a belt which we have developed in equation (5) is evidently too complex for convenient use. I have therefore attempted by a graphical method to obtain a simpler equation, which would be at the same time sufficiently correct for use in practice. For this purpose I have constructed a curve representing the width of a single leather belt required to transmit 10 horse-power upon a cast-iron pulley at various speeds, when embracing one half the pulley circumference. In the diagram (Fig. 2) abscissas represent the various speeds of the belt in feet per minute, and the ordinates the corresponding belt widths.

The most noticeable thing about this curve is that the width of the belt at first rapidly diminishes as the speed is increased, then remains nearly constant for a certain range of speed, and as the speed is further increased the belt necessary to do the work becomes rapidly wider. This effect is due to the influence of the centrifugal force, which rapidly increases with the speed, until, at a speed of about 9,000 feet per minute, the entire assumed safe tension of the belt is needed to balance the centrifugal force, leaving nothing available for the transmission of power. At this speed the required width of the belt theoretically would be infinite. This curve enables us to determine a speed at which the width of belt required to transmit any given power would reach a minimum, which speed appears to be, for ordinary materials, between 5,000 and 6,000 feet, or about a mile a minute.

To determine the effect of varying the arc of contact of the belt on the pulley, I have plotted another curve, representing the width of belt required for the same work, when it embraces only three-tenths of the pulley circumference, the arc illustrated in the figure. The required in-

crease of width for this small arc, much smaller than is ever used in ordinary practice, is not so great as one might suppose who has never calculated it. In practice the arc embraced by the belt is very seldom as small as four-tenths of the circumference, and for any ordinary case a width intermediate between these two would suffice. It should be remembered that if the width is slightly different from the calculated amount, that the only effect will be to vary somewhat the per cent. of slip, so that considerable latitude is permissible.

To ascertain the effect of variations in the co-efficient of friction, I plotted another curve representing the belt width for the same work,

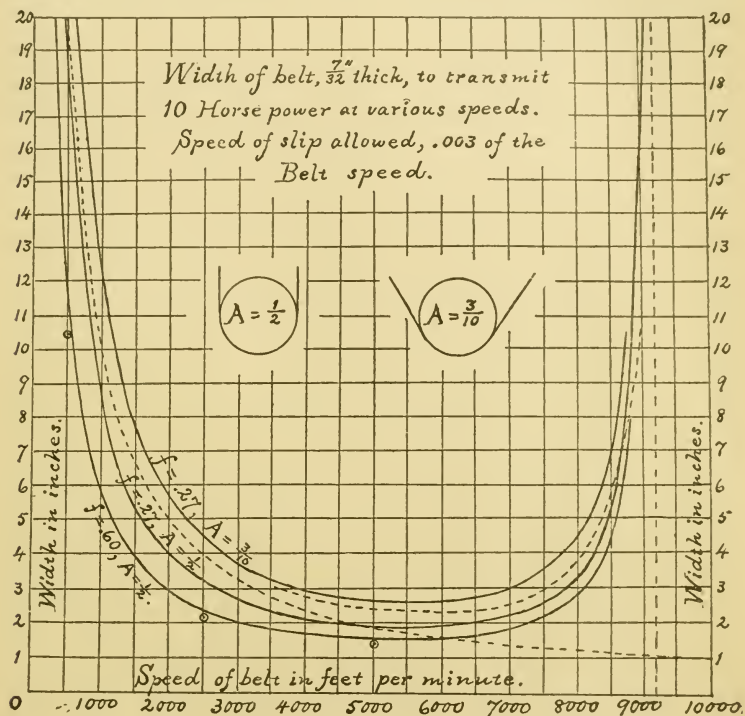


Figure 2.

and arc of $\frac{1}{2}$ circumference, corresponding to a co-efficient of 0.6 at three feet per minute, the value given for a rubber belt. Evidently increasing the co-efficient of friction more than 100 per cent. does not reduce the width of the belt more than 25 per cent.; and when the co-efficient is increased beyond 0.6, the effect in reducing the width of the belt is almost imperceptible. This is shown by the three plotted points, which represent the belt width for an arc of half circumference and a co-efficient of 1.4, which is the value indicated by some experiments for the co-efficient of a rawhide belt on a lagged pulley. This curve

indicates that in general the width of a rubber belt need be only about three-fourths as great as that of a leather belt, to transmit the same power with the same slip. As the wear on a rubber belt from slip is, however, more rapid than on a leather belt, some engineers make them of the same width, and run with less slip in the case of the rubber belt. The curve representing the width of the rubber belt also represents approximately the proper width for any of these belts on a lagged pulley. These results show also that whereas there is not much advantage in lagging a pulley in case a rubber belt is to be used, there is a great gain in doing so for a leather belt, as the belt in that case need be only three-fourths as wide, and will transmit the power with less tension, and consequently less journal friction.

In regard to formulas, it has been the writer's custom to calculate the width of belts by the handy rule that a one-inch single belt, traveling 1,000 feet per minute, will carry one horse-power; and that for other speeds, the width should be inversely as the speed. Expressed as an equation the rule would be $W' = \frac{1,000 \ H P}{V}$, in which W' is the width of a belt $\frac{7}{32}$ of an inch thick. This rule has seemed to give uniformly good results under widely different conditions, in spite of the fact that it takes no account of the effect either of the centrifugal force or of the speed of slip. It occurred to me, however, that within the limits of practice, the errors made by neglecting these two factors tend to offset each other. Thus the tendency of centrifugal force is to diminish the driving power as speed increases, while the effect of the increasing coefficient of friction is to increase the driving power with higher speed. To determine how nearly these effect neutralize each other, I plotted another curve, using the simpler formula, and found that within the limits of ordinary practice the curve is very similar to the curves obtained from the theoretically more exact equation, and that indeed, the old simple formula is, within the limits of error of our existing knowledge, quite as correct as any formula that can be made. The curve, shown by the dotted line, follows about the line that the theoretical formula would give for an arc of $\frac{1}{10}$ of the circumference, except when we reach a high speed, like 5,000 feet per minute, when the effect of the centrifugal force begins to predominate, and the curve no longer corresponds to the correct one. These speeds are beyond ordinary practice; however, the formula may be made to apply fairly well to them by adding a correction, and making it read

$$W' = \frac{1,000 \ H P}{V} + \frac{1,000,000 \ H P}{(10,000 - V)^2}.$$

The effect of this correction on the curve is of no importance until we reach a high speed; then its effect is shown by the upper dotted curve.

One of the most potent causes of waste of power in large manufacturing establishments is the excessive journal friction in engines, shafting, and machinery, caused by the pull of heavy belts which are strained up too tight. When a belt is put on, the chief concern of the man who does the work is generally to get it on tight, so that it will not have to be soon taken up. He puts his screw clamps on it, and draws it up with

a tension limited more by his own muscular power and the leverage at his command than by the requirements of the power which the belt is to transmit. He is not apt to get it too loose, except, perhaps, in the case of an unusually large belt. For every case, however, we have a definite value for $T_1 - T_2$, or the effective force which the belt is to transmit, also a definite ratio between T_1 and T_2 , depending upon the surfaces of contact and the belt speed; therefore there must be for every case a definite value for $T_1 + T_2$ (the sum of the two tensions), which, for a properly proportioned belt, may be calculated by the formulas we already have for the values of $T_1 - T_2$ and T_1 . This means that in every case there is a certain definite tension with which the belt must be stretched over the pulleys, in order that it may not slip more than the prescribed amount. In calculating this initial tension, allowance must be made for the tension required to balance the centrifugal force, and also for the increase in the sum of the two tensions, when the belt is driving its load. It is evident that the proper initial tension would vary in different cases; but it is safe to say that the force with which the two ends of the belt are drawn together for joining should not generally exceed $\frac{9}{10}$ of the safe working tension, or, for a belt $\frac{7}{32}$ of an inch thick, 60 pounds to the inch n width. On the other hand, if the belt is put on too loose, it will slip excessively, causing harmful variations of speed, and wasting power in the same proportion as the slip, besides rapidly wearing out the belt. Not only this; in a cotton mill, for example, a slip of 2 per cent. in the belts, where the power is transmitted through four or five of them before it is finally used, would cut down the entire product of the mill by from 12 to 17 per cent., the running expenses remaining the same as before. If the belts were, on the other hand, strained to unnecessary tightness, the effect would be immediately apparent in the increased power required, excessive heating and wear of journals, and larger coal, oil, and repair bills. It is oftentimes not a difficult matter to double the power expenses for a whole factory by simply varying the belt tension. These considerations should make us realize the great importance, whenever we transmit power through belts, of having them strained to just the right degree of tightness.

The proper way to put on a belt is to have the belt clamps provided with spring balances, and thus weigh the tension in putting on the belt. A belt clamp made in this way is a very cheap affair, and it is no more trouble to use it than it is to use the ordinary clamp. In any place where belts are used to transmit power to any extent, an apparatus of this kind intelligently used would pay for itself a hundred-fold in the course of a year.

The foregoing considerations also show us the wisdom of always using belts of ample width to transmit all the power required without undue stretching, and consequent change of tension; and especially is this important where no ready means are provided for taking up the slack of the belt. It does no particular harm to have a belt unnecessarily wide; but it always does harm to have it too narrow.

The great advantage of using adjustable straining pulleys is also apparent from the foregoing. The added resistance of such pulleys from

their journal friction should be almost inappreciable, and in the hands of an intelligent engineer or foreman they enable us to keep our belts always at the tension just required to drive without excessive slipping, and no more, in all conditions of the atmosphere, and without continually making a new joint in the belt to take up the slack. In the hands of an ignorant or careless man, however, who simply uses them to strain up the belts as tight as he can, they may prove an injury instead of a benefit. Where clutch pulleys, or tight and loose pulleys, are used, these straining pulleys, in common with such devices as sliding the base of a machine horizontally, or screwing it up and down, have the advantage of allowing us to relieve the strain on the belt and on the journals when the belt is not driving, and to put it on again when required. They also form one of the cheapest and best disconnecting arrangements for cutting off or putting on a part of the machinery while the engine is running.

From the curves of Fig. 2 it is evident that up to a speed of about a mile a minute the width of belt required to transmit any given horsepower becomes less and less as the belt speed is increased; therefore, in order to get the cheapest belt that can be made to do the required work well, we should make our pulleys as large in diameter as possible, so as to run our belt at the highest attainable speed, within the limit of about a mile a minute, beyond which, the width, and therefore the first cost, of the belt would begin to increase.

The greater the diameter of the pulley, also, the less power is wasted in overcoming the stiffness of the belt in bending it around the pulley; although the experiments of William Sellers & Co. indicate that the loss from this cause is generally an unimportant factor in the efficiency of transmission, the main sources of loss being *journal friction* and *slip*. Other things being the same, the loss from journal friction depends upon the force with which the shaft is drawn against the journals, which is directly proportional to the tension of the belt; and as the necessary tension of the belt to transmit a given horse-power is inversely as the belt speed, it follows that the loss from journal friction is inversely as the belt speed. Hence, from all these considerations, the conclusion is, that to attain the greatest economy, we must increase our pulley diameter as much as possible, and run at a high belt speed. By decreasing the width of the belt and the breadth of face of the pulley, a high belt speed also tends to economize space, measured along the length of the shaft, which is sometimes an important consideration.

There are two considerations which fix a limit to the belt speed. One of these is the first cost, weight, and space occupied by the pulley, all of which increase with its diameter, although it should be remembered that at ordinary speeds the width of the pulley may be diminished as its diameter is increased. Except in extreme cases, the first cost of the pulley is relatively an insignificant item. If the pulley diameter is made excessive, however, we shall somewhere reach a point where its increasing weight will give rise to as much additional journal friction as is saved by the reduced belt tension. The question of space available to swing a pulley has, of course, to be decided from the circumstances in each case. The second consideration is that the width of belt and pulley have to be

rapidly increased if the belt speed is raised above say 7,000 feet per minute; and we may therefore fix that speed as about the limit beyond which an increase of pulley diameter and belt speed ceases to be profitable.

In case several machines or lines of shafting are to be driven from a single main shaft, a saving in space can be effected by arranging the various belts to *ride* one upon another on the driving pulley. Belts arranged in this way work about equally well as they do when run side by side. There is another case, however, where riding belts do not work as well; that is when a pair of belts, one riding the other, are used instead of a double belt to connect *one pair* of pulleys. In this case the inside belt does all the driving, the outer one serving merely by its tension to hold the inner one harder against the pulleys. If the belts are horizontal, the sag will appear as illustrated by Fig. 1, as the outer belt does not slip on the inner one, but maintains a practically equal tension on both sides. A pair of belts arranged this way will not always drive twice as much as one belt alone, and putting a third belt on top of the other two makes very little increase in the driving power. One belt of double or treble thickness is usually better than this arrangement.

In regard to joining the two ends of a belt, a glued lap joint is the best wherever it can be conveniently used. The ends of the belt should be scarfed off upon opposite sides for a distance back from the end of from eight to twenty inches, according to the width and thickness of the belt, and joined with a mixture of about equal parts of fish glue and common glue, applied hot, and kept under pressure for a few minutes. To complete the work, in the case of a leather belt, wooden shoe pegs may be driven through the joint, while in the case of a cotton belt, cross rows of stitching may be used. This joint is liable to be softened and give way if the belt is exposed to very much dampness. For such cases, a water-proof cement may be made by dissolving gutta percha in bisulphide of carbon to about the consistency of molasses. This is applied like the glue, the two ends of the belt, however, being warmed before the mixture is spread on. Molesworth gives the following recipe for a belting cement: 16 parts gutta percha; 4 parts india rubber; 2 parts pitch; 1 part shellac; 2 parts linseed oil. Cut the solid materials into small pieces, melt the whole, and mix well together.

In many cases, especially where a belt has to be frequently taken up, a laced joint is probably the most convenient. A belt is of course weaker at a laced joint than in the solid parts, but as it is ordinarily strained only to about one-tenth of its full breaking strength, its driving power is not thereby reduced. The safe working stress for a belt depends rather upon its *stretching* than upon its *breaking* limit, and a well-laced belt will drive about as much as a continuous one.

To make a good laced joint, cut the ends of the belt off square and punch holes exactly opposite each other in the two ends, putting two rows of holes in each end, arranged zig-zag. It is desirable, but not necessary, to have an odd number of holes in each end, the larger number being in the row next to the end. A 2-inch belt should have three holes, a 10-inch belt nine holes, in each end. The edges of the holes should not come nearer than seven-eighths of an inch to the end, or

nearer than three-quarters of an inch to the side of the belt, and the second row should be about an inch and three-quarters from the end. Begin to lace in the middle, working out at the same time to each side and back again to the middle, where the ends of the lacing may be tied together, taking care to have the knot on the side away from the pulley. In order that the belt may run straight it is important to lace each side equally tight. The lacings should not cross each other on the side next to the pulley, and it is better not to have them cross on either side. Where the strands of lacing do not run parallel to the belt it is important that there should be the same number of strands inclined one way as there are inclined the other way, otherwise there will be a tendency to slip one end of the belt to one side, so that the ends will no longer be exactly opposite each other. It is a good plan to arrange the strands next the two sides of the belt so as to run parallel with it. A method of lacing that fulfills these conditions, without crossing the strands on either side of the belt, is illustrated in Fig. 3.

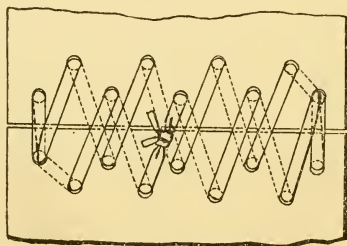


Figure 3.

Pulleys may be lagged either with leather or with paper. The leather should be put with the grain side out, stretched tightly round the pulley when moist, and fastened with copper rivets, holes being drilled in the pulley for that purpose. The paper used for lagging pulleys is usually a stout, coarse straw or wood pulp paper. To put on this covering, the surface of the pulley must first be thoroughly cleaned from grease and dirt by a solution of potash. The paper is covered with paste or a mixture of paste and glue, and wound on wet in several layers, generally not less than six, breaking joints around the pulley. When shrunk on in this way it becomes hard, and makes a firm, adhesive surface. I have seen layers of this covering wound on for an inch or more in thickness, in order to increase the diameter of the pulley.

Returning now to give definite answers to the questions asked at the beginning of this paper, in regard to the best materials for belts, I should say that for general purposes "there is nothing like leather;" but that it should always be run on a lagged pulley, unless there are special reasons to the contrary. In case the belt is to be exposed to water or dampness, and where lagged pulleys are not used, rubber belts will be found preferable. For very high speed, the cotton-leather, being

light and uniform in weight and texture, will be found to give good results.

With regard to the dimensions of the belt, I should use for a $\frac{7}{8}$ -inch belt on an iron pulley, the formula

$$W' = \frac{1,000 \ H \ P}{V},$$

with the proper correction for speeds above a mile a minute. For lagged pulleys make the belt three-fourths as wide as for iron. Make the diameter of the pulley sufficient to give as near 7,000 feet per minute speed as can be done without making it too large and heavy. These considerations will of course frequently limit the speed to very much less than 7,000 feet.

Third, strain the belt to about 60 pounds to the inch in width, for a thickness of $\frac{7}{8}$ -inch, using a tension-registering belt clamp.

Fourth, use a glued lap, or a laced joint, according to convenience.

HIGHWAY BRIDGES OF IRON AND STEEL.

BY J. A. L. WADDELL, MEMBER OF ENGINEERS' CLUB OF KANSAS CITY—
WITH DISCUSSION.

[Read December 5 and 19, 1887, and Discussed April 2 and 16, 1888.]

ABSTRACT OF PAPER.

NOTE.—The original paper having already been printed in a pamphlet of 46 pages, and generally circulated, only an abstract is here given, but the discussion (which has not been published) is given in full.

Chapter I. is introductory. It makes the statement that there is urgent need for reform in the present methods of designing highway bridges, and that the iron highway bridges built to-day in the West are often more unsafe than those built five years ago.

The reasons given for this state of affairs, are first, indifference and a lack of knowledge on the part of the people, and, second, unscrupulousness and ignorance on the part of the majority of highway bridge builders.

It states that there are throughout this country a great many structures that are liable to tumble down, and indicates where a few of them are to be found.

Four methods of effecting the desired reform are suggested, viz., 1. State inspection. 2. An association of highway bridge builders who would be bound by a heavy penalty to build no bridge that would not have the strength indicated in certain standard specifications to be adopted by the association. 3. For county bridge supervisors to call for bids on the specifications contained in the pamphlet, and a specialist examine the designs submitted, award the contract and inspect the bridge after completion; and 4, having complete detailed plans prepared by a competent specialist.

Chapter II. enumerates a number of highway bridge failures, many of which were accompanied by loss of human life, and quotes at length from a book by Prof. Geo. L. Vose, on "Bridge Disasters in America."

Chapter III. treats of bridge lettings, showing up the tricks of the

trade and how county commissioners are easily duped by the wily bridge-men. It touches also upon the other side of the question, and states that contractors have been forced to adopt the pooling system in order to protect themselves from loss caused by unfair dealing on the part of county commissioners.

Chapter IV. explains how bridges are built, and exposes the most glaring defects of design.

Among others are the following : Insufficient live loads, weak floor beams with stronger trusses, light joists, loose joints and connections, deficient portal bracing, the use of improper styles of truss for the purpose of saving a little metal, pony trusses without side bracing, long spans with narrow roadways, sections of main members so light as to permit of undue vibration, bottom chords unstiffened where buckling is liable to occur, neglecting the effects of induced stresses, the use of too thin iron, an insufficient number of rivets in the details and connections, the merest apologies for stay plates, rollers smaller than permissible, insufficient pin bearings, over-strained pins, badly stayed hand-railings, unstiffened webs in floor beams, absence of anchorage of trusses to piers and abutments, long rods not upset, inefficient extension plates on posts, inefficient chord splices, the use of rivets of too small diameter, rivet spacing longer than allowable, improper use of cast-iron, fish-bellied girders with web-section insufficient for the shear, and, worse than all these, rivets used in direct tension.

Chapter V. treats of how bridges ought to be built, going considerably into detail, but without the use of diagrams. The bridges here described are in conformity with the best modern practice.

Chapter VI. elaborates the idea advanced in Chapter I. concerning the formation of an association of highway bridge builders, explaining not only the benefits to be derived from such an organization, but also what steps it would be necessary to take in order to form the association. Although he treats this matter very carefully and concisely, it is evident from a remark made in Chapter I. that the author does not have much faith in the proposed method.

Chapter VII., which is the most important part of the pamphlet, occupying more than one-half its volume, presents a set of specifications that are intended to cover in detail the whole ground of highway bridge designing to such an extent that a dishonest designer would be unable to scamp the work to any appreciable amount without violating the requirements of the specifications. How well the author has succeeded is a matter of individual opinion ; but this much is acknowledged—that they are the most elaborate and complete set of highway bridge specifications that have yet appeared. Whether this completeness of detail is a good feature in specifications is a point upon which engineers disagree ; but considering the object which the author appears to continually bear in mind, viz., that he is writing for the purpose of effecting a much needed reform, this close attention to the designing of details is, to say the least, excusable.

Space will not permit the noticing of more than these few salient points of the specifications.

There are four classes of bridges specified, viz.: Classes A, B, C and D,

the first being for densely populated cities, the second for smaller cities and manufacturing districts, the third for country roads and the fourth for hilly districts where the loads are necessarily light, or for localities where the inhabitants are absolutely too poor to pay for heavier structures. The author discourages the building of bridges of the last class.

The floor live loads are the following: Classes A and B, 100 pounds per square foot; Class C, 80 pounds per square foot, and Class D, 65 pounds per square foot. The truss loads for short spans are the same as those for the floor, but for long spans the live loads reduce gradually, becoming 65 pounds for Class A, 55 pounds for Class B and 40 pounds for Class C, at spans of 350 feet, providing, however, that the truss loads per lineal foot are never less than the following:

Class A.....	1,800 lbs.	Class C.....	1,000 lbs.
" B.....	1,400 lbs.	" D.....	800 lbs.

For wide bridges there is permitted a reduction in live load per square foot of floor. In addition to the preceding there are specified local concentrated loads, affecting principally the joists.

The wind pressure specified varies from 30 pounds to 25 pounds per square foot of exposed surface, decreasing as the span increases, but for unusually exposed situations this is to be increased by 25 per cent. There are, however, minimum limits for the wind pressure per lineal foot of span, specified to prevent undue vibration.

Plate girders are recommended for spans up to 40 feet, triangular riveted girders from 40 to 65 feet, pony-truss pin-connected spans from 65 to 90 feet, and pin-connected through or deck-truss bridges with vertical intermediate posts and inclined end posts for longer spans.

Complete specifications are given for all portions of the floor system.

Considerable attention is paid to "limitations" of various kinds, the main object being to prevent the use of sizes so small as to reduce the rigidity of the structure.

The subject of rigidity throughout the specifications seems to hold a prominent place.

Symmetry in design, wherever practicable, is insisted upon.

The principal working stresses are thus specified.

MEMBERS.	Iron.		Steel.	
	Class A.	Class B, C and D.	Class A.	Class B and C.
Lower chord bars and end main diagonals (forged eye bars).....	10,000	12,500	12,500	15,500
Lower chords (plates or shapes) net section.....	8,000	10,000	11,000	13,000
Middle panel diagonals and counters (adjustable members).....	8,000	10,000	11,000	13,000
Middle panel diagonals (plates or shapes) net section.....	7,500	9,000	10,000	12,000
Hip verticals (forged eye bars).....	8,000	10,000	11,000	13,000
Hip verticals (plates or shapes) net section.....	7,500	9,000	10,000	12,000
Beam hangers (loops).....	7,000	8,000	.....	.....
Beam hangers (plates).....	6,000	7,500	9,000	11,000
Lateral rods and vibration rods.....	15,000	15,000	.....	.....
Flanges of rolled beams.....	10,000	12,000	14,000	16,000
Flanges of built beams, net section....	10,000	12,000	14,000	16,000

Working Tensile Stresses.—The intensities of working tensile stresses for iron and steel in the various members are to be as given in the preceding table, when the span does not exceed one hundred and fifty (150) feet.

The intensities for main diagonals between end diagonals and middle panel diagonals or counters are to be interpolated directly according to their position. If the span exceed 150 feet in length, the intensities of working stresses for chord bars and main diagonals are to be increased beyond those just given by 1 per cent. for each 10 feet of length beyond 150 feet, up to a limit of 400 feet, after which they shall remain constant and equal to those for a span of 400 feet.

The intensities of working stresses for other members than the chord bars and main diagonals are not to be increased with the length of span.

Angle irons subjected to direct tension or compression must be connected by both legs, or the section of one leg only will be considered as effective.

In members subject to tensile stress, full allowance shall be made for reduction of section by rivet holes, screw threads, etc.

Working Compressive Stresses.—For truss members of bridges of Class A the intensities of working compressive stresses in pounds are to be found by the following table :

Conditions.	Iron.	Steel.
Flat ends.....	$9,000 - 30 \frac{l}{r}$	$12,000 - 45 \frac{l}{r}$
One flat and one pin end.....	$9,000 - 35 \frac{l}{r}$	$12,000 - 53 \frac{l}{r}$
Pin ends.....	$9,000 - 40 \frac{l}{r}$	$12,000 - 60 \frac{l}{r}$

In which $\left\{ \begin{array}{l} l = \text{length of member in inches from centre to centre of} \\ \text{connections.} \\ r = \text{least radius of gyration of section of member, also in} \\ \text{inches.} \end{array} \right.$

For truss members of bridges of Classes B, C and D, the intensities of working compressive stresses are to be found by adding twenty-five per cent. to the intensities given by the above table.

For members of the lateral systems and sway bracing of bridges of any class, the intensities of working compressive stresses are to be found by adding fifty per cent. to the intensities given in the above table.

Working and Bending, Bearing and Shearing Stresses.—The intensities of working shearing and bearing stresses on pins and rivets, and the working bending stresses on pins are to be taken from the following table :

STRESS.	Iron.			Steel.		
	Trusses.		Lateral system and sway bracing.	Trusses.		Lateral system and sway bracing.
	Class A.	Classes B, C and D.		Class A.	Classes B, C and D.	
Shearing	7,500	9,000	11,000	9,000	11,000	13,000
Bearing.....	12,000	15,000	13,000	15,000	19,000	22,500
Bending	15,000	18,750	22,500	18,750	23,500	28,000

There are specified many other intensities of working stresses, referring principally to details.

The subject of riveting is thoroughly treated, rules being given that will cover all cases of ordinary practice.

In respect to quality of materials, workmanship, inspection and tests, the Manufacturers' Standard Specifications are adopted.

Chapter VIII. contains some remarks concerning the application of the specifications of the previous chapter, explaining the reasons for certain stipulations therein.

DISCUSSION.

By Samuel G. Artingstall.

I think there can be no difference of opinion as to the necessity for improvement, both in the way of awarding contracts for these works and in the design and construction, so as to secure at least a safe structure for the use of the public. The difficulty seems to me to be how this can be best accomplished. A combination of bridge builders does not appear to me as practicable, for the reason that there are too many who would try to take advantage of this combination by underbidding and building a structure which would not strictly be in accordance with the specifications, and I do not clearly see how this can be avoided unless the trustees employ a competent expert to advise, not only on the merits of the different designs submitted in competition, but also to see that the structure is built with members of suitable scantling, and that the workmanship is good throughout. In my opinion the way to get substantial highway bridges is for the legislatures of the several States to insist upon minimum strength in the several classes of bridges, and to appoint an expert engineer with such assistants as may be necessary, to whom all designs for highway bridges must be submitted and receive his approval before being built, and after erection to be examined and accepted before being allowed to be used for public use. If some such law could be faithfully executed in any State contractors will soon improve the character of their designs, and while competition would not be restricted, bridges would be safe and the public would soon gain confidence in their security.

By G. Bouscaren.

This movement against unscrupulous highway bridge builders is highly commended, but should be extended, I think, to the same class of dealers in railroad bridges.

I have very recently completed the inspection of some 600 miles of railroad, equipped with a variety of wooden and iron bridges, and with the fresh evidences of *sinful* designing collected thereby, I am more than ever impressed with the necessity of protective regulations broad enough to cover all classes of bridges. In fact, if any distinction were to be made in that respect as between highway and railroad bridges, it is quite clear to my mind that the latter's interest is by far the most important of the two.

First—Because the public has some means of redress against careless

or fraudulent awards of defective highway bridges, but it has none against railroad managers or construction companies.

Second—Because a highway bridge can be seen and criticised by any one passing over it, and attention may thus be called to glaring defects in its construction, while the true character of a railroad bridge must remain hidden to all but the inspector, if there be one.

Third—Because the number of people who risk their lives and limbs daily on dangerous railroad bridges is tenfold that who do the same on highway bridges.

The necessity for placing all classes of public work under the supervision of a competent expert who is not himself a contractor is universally admitted. Unfortunately there is no law making such employment mandatory, and if there was, it is likely that the same parties who award their work to the lowest bidder regardless of quality and quantity, would also select the cheapest "expert" regardless of quality.

A law regulating the construction of bridges should therefore provide general specifications for the same, and a competent expert should be appointed by the Governor of the State to inspect and verify the work done under these specifications.

The uniformity of specifications for all the States, although desirable, is not a matter of prime importance. I think that all engineers engaged in the independent practice of their profession agree now practically as to the main points, and the differences to be found in their specifications are but different modes of arriving at the same results.

But I consider it essential that the specifications, no matter by whom prepared, should be the work of an engineer entirely free of attachment with any manufacturing or contracting firm, otherwise the very object which they have in view would be defeated.

You will pardon me for saying that the manufacturers' and contractors' specifications, which you have made an adjunct to your own specifications, is the best example I can give of what I mean to convey.

As long as the object of the profession will be to do the most with the least money, and at the same time to place safety before cheapness, the engineer must aim to raise the quality of materials as well as the perfection of workmanship, because in doing this he eliminates many of the unknown elements which necessitate the so-called "factor of safety." Now, the manufacturers' and contractors' specifications do precisely the reverse of this.

By lowering the grades of materials and discouraging the thorough testing of the same, they introduce new elements of uncertainty, and make it necessary to *increase* the factor of safety, thus increasing the weight of material used and rendering their plea for economy an illusory one if the same measure of safety is to be retained.

These specifications were condemned by all independent engineers present at the convention where they were discussed, and the only reason which I can ascribe for the persistent effort made in favor of their adoption is to allow manufacturers who cannot produce the best grades of iron and steel to compete with those who can.

I hope that I may win you to my side in this question; but if I fail to do so, you will understand my reasons for not indorsing your circular.

I am ready and would be glad to join in any action tending to the effective protection of the public in the matter of bridges. So many of our most able men are personally interested in the question as contractors or manufacturers that unity of action in that direction cannot be accomplished without some sacrifice on their part, which, unfortunately, they do not appear, as yet, ready to make.

To the above, which was written as a letter to Mr. Waddell, I add nothing excepting to emphasize my objections to the "contractors' specifications," which are made a part of Mr. Waddell's. I should very much regret to see them endorsed generally, for the reasons given in my letter, and do not think that any unity of action tending to their support could be secured. I think it would be an easy matter for engineers to arrive at an understanding as to general specifications for highway and railroad bridges, which could serve as a standard for the regulation of that class of construction; but specifications, however carefully drawn, are of little value without proper supervision to interpret and enforce them. Hence the necessity of legislative action to give them force of law.

By W. H. Breithaupt.

Mr. Waddell's paper is most timely. Such a reform is particularly needed in the building of highway bridges in the West. Our immediate field of action is to agitate for an improvement in this State. By the laws of Missouri, county bridges are now let by public outcry to the lowest bidder. That this is not a good method of obtaining efficient work and of obtaining it at its true value has been sufficiently proved. Letting by tender is much the better way. Awarding of contract should be dependent on some one not in any way interested in any of the tenders; and to this there should be State officers as outlined in the pamphlet under discussion. The remedy there given appears to me to be much more feasible and leading to more reliable results than could be obtained by the proposed association of highway bridge builders. Right of inspection certainly belongs to the purchaser; and if he wants advice as to the article to be bought, he will go to some one independent of the seller. So in the case of the buying of bridges the purchaser would want to rely on the judgment of an outside engineer.

A scheme for State supervision might be generally outlined as follows: First, there should be a State engineer of bridges, or State bridge inspector, His holding of office, whether by appointment or election, and the former would seem much the better, should be dependent on his having had a certain number of years' experience in bridge work, and at least two years' experience in designing and in actual charge of work; and of his having successfully passed an examination, technical and practical, by competent engineering authority, State or national, the former for some reasons preferable.

The engineer should have the appointment of assistants, after they had passed a prescribed examination and otherwise proved their fitness. All bridges of any importance, say of span beyond a certain length, in public use, both highway and railroad, should then be subject to being passed on by the State engineer of bridges, either on his personal investigation or investigation by one of his assistant engineers. This qualifica-

tion as assistant State bridge inspector might be given to any engineer proving his fitness.

The author advises for spans of from 60 to 75 feet the use of pony trusses, which I take, from the previous sentence, to mean pin-connected trusses. In general it is inadvisable to use pin-connected trusses when overhead bracing is not available. Riveted trusses are stiffer, and better admit of proper fastening of batter bracing. When depth of floor—that is, distance from surface of floor to lowest part of bridge—is limited, the panel length often depends directly on this, shallow floor making short panels compulsory. But this is more often the case in railroad bridges.

The author gives the use of castings as a method of fastening lateral rods to floor beams. Use of castings in any part of the trusses or floor is inadvisable, from the fact that they are liable to break, unless made so heavy as to be bulky and uneconomical, as the author recognizes on page 38 in the specifications. I do, however, not agree with him in objecting to the use of castings in bolsters. The proper distribution of the weight on the stone is a subject generally not fully enough considered. A well designed cast bolster will do this more economically than an equally efficient wrought one, and will, from its bulk, be amply secure against breaking by vibration of the bridge. The classification of bridges for the various purposes as given is a very good one, and does not appear in any other specification I know of. It is difficult to see how wind pressure on anything but the moving load of the bridge can be a moving load.

For protection of guard rail on down grade the author specifies beveling of corner and use of flat plate. A square root angle to fit over corner of guard rail, as is largely used, is simpler of application and better when in place.

I see no use for reducing net section of bars in stiffened end panels 20 per cent. While punching holes in these bars would leave ragged edges and incipient cracks, drilling—as it is generally done or should always be done—in no way injures the material beyond what is actually cut away, in fact tests would tend to show that it is proportionally slightly stronger.

The author gives for requirements of steel, tension and pins, 60 to 68; compression members, 64 to 72; rolled bars, 58 to 66.

This is too slight a difference between tension and compression. Better have the two tension classes alike, say 58,000 to 68,000, and compression say from 70,000 to 80,000.

By W. H. Burr.

Probably no one will dispute the statement of Mr. Waddell which he has so forcibly supported, to the effect that much of the highway bridge business of the country is productive of most dangerous structures, which would not be tolerated under intelligent and honest supervision on the part of the proper county, town or city authorities; but personal examination of a large amount of highway work during the past two or three years leads me to believe that at least some highway bridge builders are doing fairly good work, and are entitled to the confidence of the public. Such builders would doubtless be glad of any movement that

has for its objects the improvement of highway bridges and the extraction of good work from the unscrupulous builders or else their extinction.

So far as the flimsy and dangerous bridges are concerned, I believe it may be confidently stated that two causes render their existence possible; one is the combined ignorance and unscrupulousness of their builders, and the other, the ignorance and possible or probable corruption of a large number of the highway commissioners in many places, both evils being aggravated by the culpable apathy of the general public. The failures occurring every month demonstrate the existence of hundreds of miserable structures, and the widest possible publicity given them is the most potent factor in dissipating the indifference of the public. Interested engineers, as well as other interested and public spirited men, should have some concerted system by which every bridge failure would receive such attention that all essential details regarding previous condition and causes would be collected and permanently preserved, together with the name of the builder and date of erection or time of duration of the structure. The amount of loss of both money and life entailed by the wreck should also be ascertained. A careful and accurate account of the failure based upon the data thus obtained should then be written and given the widest publicity both in all the engineering papers of the country and the principal dailies. By such means the general public would be brought to realize not only the great losses caused by such inferior structures, but also the imminent danger in which a large portion of the community daily traverses the highway bridges of the country. The wide publication of the names of the builders of these tumble-down bridges would be an excellent advertisement of the dangerous character of their miserable wares, and would serve to notify the public that they and their business agents should be avoided. The constantly recurring notices of these disasters and their destructive consequences would stimulate in the public mind a growth of the right kind of interest in the matter of highway bridges, and would soon effectually dissipate the existing apathy and indifference. Such a constantly educating influence would soon induce or force the appointment of capable highway bridge commissioners with at least some integrity, who would not allow those builders to bid whose names become prominent through failures.

In this or some similar manner only, I believe, can public apathy be removed and a correct public sentiment be created. Unsupported by public sentiment, license, legal enactment or commissioners appointed by the American Society of Civil Engineers or any other body will be certain to result in vain efforts whose failures will leave the evils more firmly fixed than before. With it, however, the County Commissioners will need no extraneous impulse to seek tenders from either honest or honorable and competent builders, or the services of a consulting engineer who will furnish them such advice as will lead to the purchase of a substantial bridge.

The benefits of a pool are, to my mind, not by any means clear, although I do not doubt that which Mr. Waddell proposes, if conducted in the manner he indicates, would serve to remedy many existing evils.

Whether the organization could be kept in the original channels, seems to me, in the light of human experience, somewhat doubtful.

One thing is clear, however, in fact two things are clear, the present system of unlimited and indiscriminate invitations to tender for highway work breeds most pernicious evils and is most extravagant and expensive to counties, cities and towns. Such a comprehensive method induces bids from the good, bad and indifferent, with the first in a very small minority. Good designs are thus put alongside of the most wretched clap trap, which appears under a correspondingly low figure and is usually accepted. This is the first step toward a subsequent failure near at hand. Again, traveling and other expenses and "boodle" must, of course, be paid by the public who buy the bridges, and the greater the number of bidders, correspondingly greater must be the amount of expenses and "boodle." If the wise and discreet officers of town, city or county were to put their heads together to deliberately discover a method by which their constituents should pay the greatest possible price for the poorest and most dangerous bridge that would stand up in a presentable manner long enough for the builders to get their pay, they could scarcely succeed better than to advertise their bridge lettings in the local papers in the usual manner.

Invitations should be extended to a few responsible builders only, whose reputations and known competence and honesty would be a guarantee for satisfactory designs and substantial work as well as proper methods, whether bids are mailed or submitted in person. Highway commissioners utterly unfamiliar with the first principles of engineering and an easy prey to the devices of sharp and unscrupulous bidders can ill afford to have any conference with them, and should not venture to do so; but an open advertisement brings in a swarm of such parties and generally repels the best builders, since they know that honest structures cannot be furnished at the prices of their unscrupulous competitors. Whenever highway commissioners follow the example of the railroads, and invite a small number of bids from reputable parties, they will get good work and safe structures at economical prices, and not till then. Such conditions only will reduce expenses, and eliminate "boodle."

Little need be said regarding the specifications submitted by Mr. Waddell. They are admirable, and no exception can be taken to them. The most competent engineers may differ in opinion over points of detail, but such differences are quite unimportant and of no consequence.

By C. E. H. Campbell.

Professor Waddell very truly states that the average iron highway bridge as built in the West to-day is in many respects inferior to that built five years ago. As to the causes of this state of affairs, they are many and complicated. Eight years ago the average number of bidders found at a bridge letting was six, and every one of them was capable of designing and constructing a fairly decent structure: to-day the average number of bidders is fourteen, consisting of the following variety of talent: Seven representatives of companies owning shops, and competent to turn out good work; two contractors of reliability who do not operate shops; five incompetent hangers on who follow the legitimate con-

tractors from place to place for the purpose of getting money enough from them in the way of pools to live on without working for it, and who generally have more to say and more advice to give the officials who have the business in charge than the legitimate bidders have. This is the genius who is known by the honorable and appropriate title of Scalper.

This term should apply to any man who, after receiving a contract to construct a bridge upon a certain plan and specification, wilfully and purposely cuts down the sizes of materials in such a manner as to render the structure unsafe, and as has often been done, mutilates it to such an extent that some parts are only half as strong as others. This mutilation generally occurs in the rolled channel bars, lateral systems, floor beams and small details. The sizes of bar iron are seldom if ever changed, because even a County Commissioner can measure them and discover the shortage. The diagrams of stresses which are submitted by the majority of bidders and the sizes of materials specified are generally correct, but a comparison of this diagram with the structure as built is what will tell the tale. This is rarely, if ever, done.

It may be asked how are communities going to avoid the existing state of affairs. It seems to me that one of the easiest methods would be to refuse to entertain a bid from any person who is not prepared to demonstrate his ability (theoretically, practically and financially) to build the bridge desired. Then to control the proclivities of those who may be called competent builders would not be such a difficult matter. A community could either employ an expert engineer to make designs for their work to suit their requirements and means, then invite bids on said designs, and retain their engineer to see that the contract was carried out in every particular, or, if they accept the tender and designs of any bidder, require him to furnish copies of his working drawings to submit to the inspection of an expert, or if they cannot afford to do all this, let them accept what appears to them to be the best plan and specification and bid, from one of the bidders, then place the county seal on all papers, and not permit them to pass out of their hands or be changed, and when the bridge is complete to take these specifications and go over every part of the structure and measure the sizes, and if they find any variation from the specifications that upon investigation diminishes the capacity of the structure from that represented by the contractor, refuse to accept or pay for the bridge until the scant parts are made good. There is no honest or responsible contractor who will be afraid to accept these conditions, and any man who would not agree to the same should not be awarded a contract. The contractor should also be held accountable for any and all defects of construction that might be discovered even after the bridge had been accepted and paid for.

From the foregoing remarks it may appear that I have taken sides with the public against the highway bridge builders of the country. This is not my intention by any means. It may not be amiss to state that I have had an experience in building bridges in the West that covers a period of eighteen years, and have in that time come in contact with a great variety of public officials, and while I have many pleasant recollections of honorable and fair treatment from this class, I have also many of the opposite.

That close and niggardly dealing with contractors by the public occurs in many instances is a fact. That favoritism and prejudice have cheated many a contractor out of his just dues after being invited to bid on the work is another fact. That the unfair treatment of responsible contractors by public officials was the principal cause that produced the method of business known as pooling is another fact.

I believe it was my privilege to attend the first bridge lettings in the West where pools were formed, and the bidders present resorted to this method as a means of self-protection, for the reason that we could discover in a majority of cases a pre-disposition on the part of the officials of various counties to give their work to certain individuals, regardless of the claims or rights of the lowest responsible bidder. This would not have hurt so badly if they had sent for their favorite and given him their work to do, but they would send out invitations to every bidder in the country that they could hear of, and after the bidders had gone to considerable expense in preparing, perhaps, special designs for the work and traveling two or three hundred miles to the place where the contract was to be let, they would find upon investigation that a certain company had the "inside track" and would get the work if it were possible for the officials to give it to them. This was not a very pleasant matter to discover, and naturally led the contractors to devise some means of getting their expenses out of the community who had trifled with them. This method of doing business served its purpose as long as it was not abused, but in time it degenerated, and the fruit it bore was the "scalper," and the modern bridge-letting illustrates how the business has been carried on up to 1887. At the present time pooling is rather the exception than the rule.

The Professor proposes an association of highway bridge builders for the purpose of advancing the standard of work, and at the same time securing a fair remuneration for same. This is very desirable, but to form such an association is a difficult matter, owing to the jealousy existing between manufacturers, before mentioned. But should such a thing be attempted, it seems to me that the first order of business should be to compile and unanimously adopt a complete set of specifications that would cover every possible case in the highway bridge business. This being done it might not be possible to arrange the financial part of the matter, but if every company would agree to stand by the adopted specifications and put up a money forfeit as a guarantee of good faith; the bridges of the country would be well built, and contractors would certainly make as much money as they now do.

An association was formed a few years ago in which some twenty companies were interested; it was conducted in a first-class business-like manner, and was a financial success to all parties who stood by their obligations. The bridges were very fairly built. One of the largest companies in the country started to abuse its privileges, and get all the contracts, others followed and the association was dissolved at the expiration of the year, much to the regret of many companies who had endeavored to live up to their agreement.

I will not attempt to review or criticise the specifications in detail to any extent. That they are exhaustive, no one can deny. That they

treat of every necessary condition and case in the detailing of iron highway structures is apparent, as far as my knowledge goes. That they are rather voluminous may be an objection raised by some bridge designers, but I look at such matters in the light that when a man undertakes to write on such a subject he does not want to leave anything out. And designers who may make use of these specifications can allow themselves such latitude as their individuality suggests, without violating mechanical laws to any great extent, and their bridges will be practically perfect.

In conclusion, I may add that thus far I have had in view the well settled and comparatively independent parts of the Western country, whose people and traffic demand structures that are unquestionable in their capacity. But let us move farther west to the frontiers of civilization, if you please. Here we find new counties but lately organized. People are comparatively poor, but they have to travel, and the streams are in many cases just as important as in this part of the country. The people can ford these streams when the water is low, but do not want to run the risk of doing so when they have floods. They have a limited amount of money; they want a bridge. Materials are expensive on account of the distance from point of production. They call on an engineer to help them out by designing a bridge that can be built for the money they have. The engineer finds that he cannot do it and conform to standard specifications. What is he to do in such a case? It is quite a problem for him to solve, in which the element of chance plays the most important part; and the result to be determined is the difference between the chances of fording a dangerous stream or crossing a weak structure. I think that most of us would take the chances of crossing the weak structure, and would build it for them too. But in such cases the necessity of employing the skilled engineer who is master of his profession is apparent.

By W. L. Cowles.

I have read the specifications carefully, and am glad to say that, as a whole, they are calculated to insure work of the very best quality. They are very complete and cover all the details of design and construction fully. There are, however, a few points which, it appears to me, might be modified with profit, one of which is the specification at the foot of page 28, relating to the proportioning of sway bracing.

The intent of the method specified is evidently to equalize the stresses on the two trusses, as nearly as possible, by means of the sway bracing. At least this is involved in assuming that the trusses deflect equally. This appears to me to be unnecessary, as the heavily loaded trusses can never be thus loaded to its calculated capacity, and this condition is not likely to occur more frequently with one truss than with the other. Moreover, this method of proportioning would rarely give as heavy bracing as other considerations would call for. For example, it would require a load of 100 pounds per square foot on a 30-foot roadway, with a panel length of 20 feet and a depth of truss of 25 feet to call for a one inch round rod, which is as small as I think should be used in sway bracing, and a bridge of such or equivalent dimensions ought to have still

larger rods. If it is desired to carry the wind pressure on each panel to the bottom chord and thence to the end of the bridge, this would furnish a desirable specification. If not, it would be sufficient to specify the minimum size of rod to be used, and better than to use a principle which I conceive to be erroneous.

The specification near the top of page 31, concerning the connection of angle irons in direct stress, I cannot see the reason for, although I am aware that it is used in other specifications and by good authority. It is undoubtedly desirable to connect both legs when possible, but when it is impracticable, as, for example, in an end vertical in tension, composed of angles, I see no reason why the total net section should not be considered as effective, for the stress transmitted by the rivets is, it would seem, distributed through the entire section as effectively in an angle as in a bar. If it is argued that the stress applied to one leg cannot be effectively transmitted to the other leg "around a corner," then the same argument applies to the connection of angles in lattice girders mentioned on page 16—by auxiliary pieces of angle iron—a very nice connection for avoiding the use of a large gusset, but entirely unnecessary, as I consider, as a means of developing the full strength of the member, for if stress cannot be transmitted from one leg to another in a long angle it certainly cannot in a short one. This specification is harmless except in the matter of a lack of economy, but another specification strikes me as definitely detrimental to good results; I refer to that one near the foot of page 37, requiring uniform pitch of rivets in the compression flanges of stringers.

It is generally necessary to make the pitch very close at the ends where the actual stress is small but the increment large, and where the full section of the flange is not required. At the centre, where the stress is a maximum and the increment a minimum, this close pitch is not required, and while it may be said in general that a rivet in compression is as good as the section cut out, still in a case like this it appears to me that the punching of holes as close as is required at the ends must break up the iron in a way that makes it less effective than it should be at a point where the entire section is required by the stress.

With the exception of these points the specifications seem to me to be peculiarly well adapted to their purpose, viz.: as a guide and a standard for those who are compelled to rely on the manufacturer through entire lack of knowledge on their own part as well as to those manufacturers themselves who are deficient in technical knowledge.

It is certainly very desirable that there should be a recognized standard, but still more necessary that there should be some authority to compel the use of the standard. It will be useless for engineers and bridge builders to agree upon a standard unless the buyers of bridges are obliged to purchase such only as conform to this standard. And this must be effected through the legislature directly, for the people are indifferent, trusting confidently in those of their number who are selected to buy the bridges; and it is impossible to convince these latter that they can be deceived in the character of the structure procured—for is it not warranted?

But those having the power must be convinced of the necessity of appointing a state engineer, or of licensing a certain number of engineers,

from one of whom a certificate of the quality of every bridge must be obtained and deposited with the state.

The confidence of county commissioners in themselves is illustrated by an incident which recently came under my notice. A city having a number of large bridges to build let contracts for some of them, and afterwards discovered that they had paid much more than they ought in the shape of pool. The commissioners claimed that profiting by experience they could not again be taken in in this way, and proceeded to let some more contracts. The result was that they again furnished a large amount of pool, but I doubt whether they are aware of the fact to-day.

As is very ably shown in the preliminary chapters of the "Specifications," all this would be avoided, and much money be saved to the purchasers, if excessive pooling on inferior bridges were abolished, as it would be naturally if all bidding were upon standard specifications, and the plans were subject to the inspection of a state engineer.

By Palmer C. Ricketts.

Any one who has had experience as an engineer in highway bridge building must recognize the force of the statements made in that pamphlet as to the quality of the majority of them and the questionable methods often employed to secure contracts.

As to improvement in the quality of these bridges, the only method, in my opinion, is the employment of competent engineers to supervise their design and construction; but when it is remembered that the number of railroad companies in this country which have their bridges so supervised is in the minority, the average highway commissioner can hardly be expected to be more wise.

When the use of questionable methods to secure contracts is considered, the old saying that "It takes two to make a bargain" should be remembered, and the consideration of a general method for the improvement of the morals of highway commissioners in connection with those of highway bridge builders would be appropriate.

In the opinion of the writer competition will always prevent an efficient combination of any class of bridge builders, especially of highway bridge builders, as it has always prevented in the past efficient combinations of makers of unprotected articles which require for their manufacture comparatively inexpensive plants.

It is unnecessary to say that Mr. Waddell's specifications are first rate and that a bridge built under them would be a first class structure.

By C. L. Strobel.

I am heartily in sympathy with any effort to improve the present practice of highway bridge construction, but I attach little importance to general specifications for the accomplishment of this end, and I think an association of highway bridge builders on the plan and for the purpose outlined impracticable.

I hold that good results cannot be obtained by the system now in vogue, of receiving bids accompanied by designs under general specifications. Under this system the plans are competitive, and it is left to the engineer in charge to decide which is the best plan for the least money.

This is always a difficult task. He is expected to throw out inferior plans, even though they do not conflict with the specifications, if he finds that these plans do not furnish the most suitable bridge or the best in ultimate economy. Even if it were easy to decide this question, the duty is a most disagreeable one. It requires considerable force of character, and it subjects the engineer to the suspicion of favoritism. If he holds a position of public trust, he cannot well afford to incur this. Assuming, however, that he is competent and ready to make the proper decision, has he the power to carry it into effect? Often not. In most cases the contractor whose bid is the lowest will get the work, even if his design is faulty. In other words, contractors receive no encouragement to design work to the best of their ability. They very seldom get more than thanks for their trouble.

Another difficulty is this: General specifications permit of different interpretations. By adopting certain refinements of calculation, such, for instance, as the consideration of secondary stresses, a bridge can be made to cost much more than the contractor estimated. Under the usual form of contract the contractor depends upon the fairness of the engineer to a great extent as to what interpretation shall be placed upon the specifications. This is not business-like. To protect themselves in cases where engineers in charge are known to be unreasonable and one-sided, contractors are sometimes obliged to increase their prices to cover such contingencies, or they do not bid at all. If the engineer in charge is a bridge expert, and he ought to be, he will be competent to prepare his own specifications. He ought not only to do this; he ought also to prepare complete detail plans, and bids should be received on these. Cities and counties should be encouraged to engage bridge experts for this purpose. The question of compensation can be regulated in the same manner as done by architects. Rates should be established graded for different classes of work, and an understanding reached among engineers that charges shall not be less than these rates, though they may be more, subject to special agreement. The main reason why it is so difficult to get pay for engineering work is that there are no established rates.

Lastly, some pressure must be brought to bear upon county commissioners, and this can only be done by the appointment of State engineers, whose duty it shall be to examine and report upon bridges, to whom plans of public works shall be sent for record, and who will be expected to recommend to the legislature measures governing the construction of public works.

By Edwin Thacher.

Mr. Waddell's general specifications for highway bridges appear to be very complete, and if generally adopted would undoubtedly result in giving us much better and safer bridges, as a rule, than we now have. It will not be necessary to mention in detail the many good points in the specifications, as I suppose the Engineers' Club is more desirous of obtaining criticisms than commendations.

The greatest objection I have to the specifications is their great length, occupying twenty-four pages of closely printed matter, while it appears to me that all necessary directions could be easily condensed into one-

third of this space. Unless a specification is reasonably brief a busy calculator cannot take time to read it understandingly, and many provisions are liable to be overlooked. I would prefer to have general directions sufficient to insure a first-class bridge and leave most of the details to the designer.

I will notice a few points which I believe could be changed in the interest of simplicity without detriment to the specifications. The author uses live loads ranging from 40 to 100 pounds per square foot in multiples of five pounds, or thirteen varieties altogether. This is a matter of individual judgment at best, and it appears to me that four or five varieties would be sufficient.

Again, he makes the intensity of live load on sidewalks only four-fifths of the maximum on roadway. The heaviest uniform load that a bridge can be subjected to is a crowd of people, and if a bridge has sidewalks the crowd will take them in preference to the roadway. The rules given for the calculating of bridges with sidewalks are an approximation complicated and difficult to remember. They also err on the side of danger. With these rules omitted a correct calculation could be insisted on, and the calculation would, at the same time, be simplified. The weights assumed for timber appear to be rather light. The most thoroughly seasoned timber, only one inch in thickness, usually somewhat exceeds these weights. The small allowed variation between the actual and assumed dead load would too often result in recalculation. It should be sufficient to specify that the actual should not exceed the assumed load by more than, say, 3 per cent.

Under the head of "wind pressure" I think it would be sufficient to say that the lateral systems shall be proportioned for the following uniform rolling loads, viz.:

Unloaded chords, 125 pounds per lineal foot;

Loaded chords, 250 pounds per lineal foot,
adding two pounds per lineal foot for each foot exceeding 200 feet in the length of span.

It does not appear to me necessary to use a deflection formula for floor joists. Injurious vibrations are not caused by uniformly distributed loads, nor by wheel loads, but by the tramp of animals which bears no relation to the rolling loads assumed. The author appears to make no distinction in the strength of white and yellow pine, whereas the long leaf variety of the latter has about the strength of oak, except in resistance to shearing by sliding on the grain.

I think that the appearance of the bridge would be much improved by substituting for the hub planks or clumsy wooden hand railing specified by the author, a much lighter and neater hand railing protected by a guard rail of sufficient width to prevent the hubs from coming into contact with it.

The author gives preference to quadrangular forms of truss, but the writer much prefers triangular forms. Adjustable members are a bad feature in any bridge. They are liable to get out of order, and are subject to great abuse by unskilled inspectors.

I do not see any necessity of limiting the length of spans for double intersection trusses so long as the sizes of sections are limited, as mini-

num sections can be used in single as well as double intersection trusses. The table, limiting the length of span for different distances between centres of trusses, does not appear to me consistent, giving about 11 diameters for 140-foot spans and about 23 diameters for 500-foot spans.

The top chords and end braces of a bridge may properly be considered as a long latticed column, whose length is the distance between end pins, and whose depth is the distance between trusses. This long column is subjected to the same stress per square inch as each individual panel length, and if it have a greater number of diameters, or more properly a greater radius of gyration than the panel lengths, the allowed stress per square inch should be correspondingly reduced, and as a maximum limit I would not allow the span to exceed twenty times the width between centres of trusses.

In finding the maximum effect of wind pressure on batter braces, bottom chords, trestle bents, etc., the author supposes the structure to be empty: such assumption gives only maximum counter stresses. The maximum stresses of the same kind as are produced by vertical loading occur under a full dead and rolling load.

I do not think it necessary to stiffen the end panels of the bottom chord, particularly in highway bridges. The chances are not one in ten thousand that they will ever be subjected to compression, and to stiffen them adds quite materially to the cost of the structure. Neither do I think it advisable to fasten the wooden joist rigidly to the floor beams, as the expansion and contraction of the iron due to stress or temperature will result in bending the floor beams, this effect increasing rapidly from the fixed to the roller end of span. If the ends of the bridge are properly anchored, due allowance being made for expansion, any possible reversal of stress in the bottom chords is resisted by the masonry, which is abundantly sufficient.

The specifications provide that the top chord and end brace sections shall consist of two channels with plate of uniform thickness above and lacing below. With such section it is not possible to place the pins in the same straight line and in the centre of gravity of the sections, and the use of the top plate at all for spans under say 125 feet in length, I consider the very worst feature of ordinary highway bridge construction. For such spans it is not practicable to place the pin much, if any, above the centre of the channels and leave room for the heads of the eye bars. In such unsymmetrical sections the eccentric stress is enormous, and when combined with the direct compression will ordinarily reduce the factor of safety fully fifty per cent.

Take for example an average case of two light 5-inch channels with a $12 \times \frac{1}{2}$ inch top plate—the safe strength per square inch of the combination is only about 47 per cent. of two channels of the same depth, laced on both sides. It is also much better to have every part receive its stress directly through the pins than indirectly through the rivets.

I would prefer to have only one class of bridges instead of four, the assumed uniform and concentrated rolling loads varying with locality, but everything else remaining the same, and I would consider a factor of safety of four with ordinary allowance for impact sufficient for any case. Railroad bridges are liable to get their maximum assumed load

every day, and several times a day, but a highway bridge in all probability will not get it once in ten years, if ever. This change would much simplify calculating and make an old estimate occasionally available. The specification assumes that no part of the web shall be considered as flange area, which is quite a common assumption. No rule, however, can prevent one-sixth of the web acting as flange area in each flange, or a portion of the web from taking the same stress as the angles between which it is riveted.

The author specifies that splice plates on plate girders shall have two rows of rivets on each side of joint, and that the thickness shall range from $\frac{1}{4}$ to $\frac{7}{16}$ inch.

Cases are rare even in railroad girders when $\frac{1}{4}$ -inch plates with one row of rivets are not more than sufficient to take the shear.

The use of rods with bent eyes is forbidden, but in the writer's opinion such rods are sometimes very desirable, and far preferable in every way to nine-tenths of the substitutes for them. Tests on bent eyes made at the Keystone Bridge Works gave very satisfactory results. In submitting proposals the author calls for more work and expense than a bridge company can afford to be subjected to.

A sample strain sheet and specifications would be as satisfactory to an expert as anything further, and if not submitted to an expert, it matters little how much is shown. It should be sufficient if full detail drawings are submitted for approval before work is commenced.

So long as time lasts many good engineers will honestly differ regarding many points in a specification. Indeed, he would be a poor engineer who had no preferences. It appears to me hardly possible for all to agree on any one specification for highway bridges any more than has proved to be the case for railroad bridges.

Almost any of the specifications used by bridge companies are safe enough, and those are the best which give the greatest strength for the least money. The trouble is not so much in the specifications as in seeing that the specifications are faithfully carried out. This can be accomplished at a small expense by employing an expert of known ability to examine plans and strain sheets, and a competent inspector to examine sections, material and workmanship.

By A. J. Tullock.

I fully appreciate the difficulties we have to contend with in the present methods of letting contracts for public bridges. Owing to the fact that these lettings are in the hands of public officers, who are not familiar with the nature of the work to be done, nor able to discriminate as to the merits of proposals for doing it, I do not see any practical way of improving it, except by advocating the employment of proper consulting engineers, to take charge of such lettings.

If this can be accomplished, I would be very glad to co-operate with your Society, in any effort they see fit to make in that direction, and I think that most contractors, who have met with these difficulties, will gladly assist you.

By George L. Vose.

I hardly see how the proposed association is to be carried out. It is very easy to define what a good bridge is, and the good companies would be quite willing to agree to build nothing not up to the mark. Indeed, they have virtually done it already. But the trouble, it seems to me, will be to make the dishonest concerns that do so very large a part of this work, and who make their money by using an insufficient amount of poor material, agree to running the risk of losing their occupation. If the bad companies are forced to work up to good specifications their work will cost so much as to spoil their present profit, and they know it. If the bad companies cannot say to the town and county officers, "We will make you a *cheaper* bridge than the good companies will," their occupation will be gone. The bad companies care a good deal more about this kind of work than the good companies do, and I should think would be very apt to combine among themselves to keep it in their hands. I doubt very much if any organization can dictate to county commissioners what quality of bridges they shall build. The means used by the disreputable concerns to influence town and county officers are very potent. These officers, in most cases, don't want to be convinced, as far as I have known them. The fact that one concern offers to build their bridge *for less money* than another one is very apt to overbalance all other considerations. It is very hard to make a public officer understand that a factor of safety of two is not just as good as one of four. If one of these agents, with a good "gift of gab," tells them that the greatest possible load they can ever put on their bridge is not *a half* of what would break it down, they regard it as a wonderfully strong bridge, and as everything they need.

While I should welcome an association, or any other method for correcting the present evil, I hardly see how the plan of Professor Waddell is to effect the needed reform. There is, however, a power behind town and county officers, viz., public opinion; and, although the method is a slow one, I believe that a persistent endeavor to enlighten the public, and a timely sermon whenever a disaster furnishes a text, is about the only way to improve matters.

By De Volsen Wood.

Having had no experience in "bridge letting," I am not qualified to enter minutely into the details of the subject, and will only make one or two brief observations.

The evils of a community or of society are not removed by merely changing a system, and much less by shifting an organization. Any particular evil may be greatly modified and substantially removed by either of those methods, but new evils are liable to spring up which may be more burdensome and more difficult to remove than the former. Evils grow out of the selfishness of men, and the desire to make profits will be just as strong with an "association of bridge builders" as without, and if such an organization becomes successful it may be used to secure an unjust profit.

The evils complained of in Chap. III., bridge letting, exist, and their excessive abuse lies partly in the fact that the commissioners who are to

let the contract are ignorant of the "ways that are dark." I think that the evils complained of would be modified, if not entirely corrected, if commissioners were thoroughly acquainted with the fact that they are made to pay all those expenses in some way. For then some way would be devised by which they could be properly estimated and justly allowed. I am aware that even in this case there would be difficulty in managing the matter, but the "inevitable" would compel some kind of an arrangement. Would not the evils complained of be avoided if the commissioners would "buy" their bridges, as a man buys what he wants by going into the market? In this case the commissioners would go to the builders and would see the necessity of being paid for time and expenses, and it would save certain expenses of the builders.

Again, let the commissioners employ an engineer to make a design and specification, and get estimates on those of such builders as they might select. (Would such an engineer be so selfish as to tax the builder a commission?)

It would not remove the evil by the commissioners agreeing to pay a certain amount for these expenses, for the "bidders" would probably treat this as so much clear profit, and make their "pool" as before. It would probably work like the "tipping" system in England. Formerly the servants in hotels, etc., depended upon gifts from patrons, but the patrons proposed to the proprietor to include the servants' fee in their bill and *give* nothing to the servants, and they do now include servants' attendance in their bill; but the custom of "tips" was so strong it was not banished, and now the traveler pays both the "bill" and "tips."

I trust that the agitation of this subject will result in a proper adjustment of these expenses, and so make them legitimate in *form* as well as in fact.

By Octave Chanute.

Of the number of remedies proposed for improvement in the present system of letting the construction of bridges, the one most advocated seems to be legislative action, and I will submit the following resolutions which have been suggested to me by this discussion.

Resolved, 1st. That a committee of three members be appointed by the President to prepare and submit to this Club a form of memorial to the Legislature of this State, together with the draft of a law inaugurating a proper inspection of bridges, and that for this purpose the Committee may consult with public spirited counsel, but without incurring expense except by special authority of the Executive Committee.

2d. That the Secretary be instructed to notify other engineering societies and clubs throughout this country of the action taken by this Club, and to solicit their co-operation in this movement.

3d. That in case of the appointment of similar committees by other societies, the Committee of this Club be instructed to confer and to co-operate with them in drafting the project for the proposed law, and in drawing up general specifications and rules to guide the State inspector.

Upon the main question and the statement of facts there is no divergence of opinion among those we have heard from. The ignorance of

the county commissioners is the main difficulty, and this we must accept as it is.

It is an irremediable trouble. They desire to save money, and fear public opinion, and the result is an unsafe structure. I believe there are within ten miles of this city a number of bridges which invite collapse.

The bridge builders would prefer to put up good bridges rather than poor ones, but their interest in the profits is such that there are many of them who will supply any demand, even if it be for a poor bridge. It follows, therefore, that any reform which is to be supported by the bridge companies must be compulsory on all of them. Of course, it is desirable that the county commissioners should employ experts to aid them in the inspection and selection of the plans submitted; but the effort to accomplish this has proved so futile that I believe it is useless. The adoption of any uniform specifications has also been impossible, although tried. In 1873, after a fatal bridge catastrophe in Illinois, the American Society of Civil Engineers appointed a committee to determine the best means of averting such disasters in the future. This committee was in existence four years and finally dissolved without reaching any conclusion, the various members having disagreed on numerous points. The public naturally concluded that if engineers could not describe accurately the difference between a good and a bad bridge, that there probably was not very much difference any way.

The objection to the appointment of a state officer to inspect bridges is, that such office may become a political engine, and perhaps even defeat the object for which it was created; but this I think can be avoided by the adoption of suitable means for the selection of this officer.

Another objection is, that the creation of the office might tend to divide the responsibility, which is now entirely with the bridge company. The endangering of life under the present system ought to have much more consideration than the fact that the responsibility for accidents might be divided under another system. Another objection which might be raised is the cost of supporting the office of State Bridge Inspector. I think that the office might be made self-supporting by having suitable fees allowed the officer for bridges inspected.

The discussion of the appointment of a State officer is in such shape now in various clubs that if the members of this Club take action so as to bring the matter before the Legislature of this State next winter they will not be alone; for similar action will be taken simultaneously in other States, and the public discussion thus provoked would undoubtedly aid in the passage of the various acts.

By J. A. L. Waddell.

When advocating a very general discussion of my specifications, I did so with the hope of discovering points to be modified, corrected or omitted in the second edition of the work, which edition will soon be issued. My desire has been gratified, and I think it will be found that the second edition will be an improvement upon the first. Of course it has been impossible for me to adopt the opinion of every engineer who has discussed the specifications, for no two engineers will agree exactly

upon everything, besides, if I tried to do so, the specifications would lose their individuality, and would of necessity conflict in different parts. Nevertheless, I have considered carefully each point that has been raised, adopting some suggestions, modifying and partially adopting others and rejecting the remainder.

Those adopted in part or in whole I will now discuss, and will give also my reasons for not accepting some of the others. Time and space, however, prevent me from discussing each and every consideration mentioned in the discussions.

In reference to vertical sway bracing I have concluded to change my method of design, leaving it to each designer to proportion the rods. The specifications will prevent their being made less than an inch in diameter. It is especially to bridges with sidewalks that my method of unequal loading would apply. Take for instance a bridge of 24 feet roadway and two 8 feet sidewalks, the panel length being 20 feet and the truss depth 32 feet, and assume that the top chord width is $1\frac{1}{2}$ feet, also that the clear headway is 14 feet, which can be obtained by placing the overhead strut half way up the post. Take 100 pounds on roadway and 80 pounds on sidewalk. The transferred load in round numbers is 14,500 pounds, which multiplied by the secant (1.9 approximately) gives 27,550 pounds. Using an intensity of 15,000 pounds makes the section required 1.84 square inches, calling for at least a $1\frac{1}{2}$ -inch round rod, a size considerably greater than would be put in by guess work. If we were to proportion the rod to resist the transferred load due to a wind pressure of 150 pounds per lineal foot on the upper lateral system, the diameter required would be theoretically only about $\frac{3}{4}$ inch, and it would make no difference whether there were sidewalks or not.

Moreover, it is not consistent to proportion these rods for load transferred by wind pressure, unless we make the lower lateral system strong enough to carry the total wind pressure above and below.

But as the structure would not be endangered were the rods under consideration entirely omitted (provided the portal bracing be properly designed), I shall, as before stated, omit from the specifications everything pertaining to this matter.

Angle irons should be connected by both legs, so as to avoid causing a bending moment on the piece. In order to develop the greatest strength, the riveting in one leg should extend well beyond that in the other. This is especially true for tension members of angle iron.

The reason why a uniform pitch of rivets is advisable for iron joists and short longitudinal plate girder spans is that it provides for heavy concentrated loads, in respect to both longitudinal and vertical shear.

In reply to some of Mr. Thacher's remarks I would state as follows :

1. That the specifications are made of unusual length for the reason that they are intended mainly as a safeguard against dishonesty and incompetency on the part of bidders. If commissioners were to state that they require bids upon these specifications and upon these only, and that they intend to submit all the designs to a competent engineer, highway bridge builders would soon become accustomed to designing bridges according to these specifications ; and as the latter are very complete in detail, the consulting engineer, with very little labor, by beginning with

the lowest bid and working upward, could readily determine which is the lowest bidder who complies with the specifications. Then, when working drawings are submitted, the engineer could hold the contractor strictly to specifications, for every detail is covered.

If for every bridge letting it were necessary to have an engineer prepare special specifications, a great deal of useless labor would be involved, and the majority of the specifications would be incomplete; for it costs money to get up specifications such as mine.

It is customary among bridge designers to make the sidewalk live load less than that for the main roadway, because of the less probability of the sidewalk receiving the maximum load of people. The truth is that such live loads as 80 and 100 pounds per square foot are nominal. They contain a percentage for impact and vibration. Actual loads rarely reach the lower of these figures. The element of impact or vibration should be greater for the main roadway than for the sidewalk on account of the greater frequency of the loading and its more active character.

My weights of timber per foot board measure might, perhaps, be increased advantageously by one-quarter of a pound each, although I think that the lumber when seasoned will not exceed in weight the figures that I have given.

I employ the deflection formula for joists as a check on the tendency to use small depths, as well as to prevent vibration. Moreover, the two formulæ in my specifications, when used together, will for all cases give just the size of joist which my judgment determines to be best. It might simplify matters to use tables of dimensions of joists to cover all cases.

The Pratt truss, in my opinion, is preferable to the Warren for two reasons. 1st. It is slightly more economical of material; and, 2d, it permits the riveting of floor beams to posts, which is decidedly preferable to suspending them as they are generally suspended. Beams suspended by non-adjustable hangers and securely stayed against all motion make undoubtedly good construction; but it is expensive construction, and no better than that afforded by riveting beams to posts.

It may be well to use Mr. Thacher's $\frac{1}{20}$ th as a limiting ratio of width to the length of span, but it would not be well to employ it as a constant. For instance a 400-foot span 20 feet wide would be all right, while a 200-foot span 10 feet wide would not. The reason for this is that the longer the span the less the probability of its ever receiving the maximum wind pressure over its whole area.

I still adhere to my method of proportioning bottom chords to resist the compression due to wind pressure, where such occurs. What is the use in proportioning the lower lateral rods for a wind load, which, if applied, would buckle the windward bottom chord and destroy the structure?

I agree with Mr. Thacher concerning the necessity for balanced sections and shall modify my specifications accordingly.

As for relying upon the webs of beams to resist bending, I have at times used both methods. That of counting in the web is more exact, but that of rejecting it is more convenient. By adjusting the intensities of working stresses the two formulæ may be made to give practically equal flange areas for all ordinary beams.

Although we may state that it is the function of the web to resist shear, still it does aid in resisting bending, hence my reason for specifying sizes of web splice plates which Mr. Thacher considers excessive.

In answer to Mr. Breithaupt I would say that my reasons for reducing intensities of working tensile stresses in stiffened end panels of bottom chords are :

1st. The rivet holes in the eye-bars are very liable to be punched, even if drilling be specified.

2d. That riveting on the stiffening induces initial stresses in the member. And

3d. In order that I may be to a certain extent in accordance with the gentlemen who are advocating the use of the Launhardt-Weyrauch formula, which, by the way, I see no necessity for using unless the reversion of stress be rapid and of frequent occurrence.

The *Indian Engineer* objects to my using a pressure of 300 pounds per square inch on masonry, and rightly so for some masonry.

In the second edition I shall use a sliding scale of pressures varying from 130 pounds for brickwork up to 500 pounds for granite of best quality.

There are other points in my specifications criticised besides those above mentioned, but the differences involved are simply those of opinion.

It is very gratifying, indeed, to me to have the matter of reform in highway bridge building taken up in such a thorough and earnest manner by the Engineers' Club of Kansas City, and to see that the move which they are making is being followed by many of the local engineering societies throughout the country.

Concerted action on the part of these societies, tending towards legislative action, ought eventually, if continued long enough, to accomplish the much needed reform to which my efforts have for many years been devoted.

CHARLES LATIMER AND W. L. BAKER.

MEMOIRS BY JOHN W. WESTON AND G. A. M. LILJENCRANTZ, COMMITTEE OF
THE WESTERN SOCIETY OF ENGINEERS.

[Read September 5, 1888.]

It is with sincere regret that your committee finds itself called upon to place on record memoirs of departed members, and the following meagre tributes to two men, from whose separate lives and characters we believe we may each gather lessons, which assimilated, will help us, are respectfully presented that all our members may join us in our sorrow.

CHARLES LATIMER, OF CLEVELAND, OHIO. DIED MARCH 25, 1888.

* * * * *

Charles Latimer was born in Washington, D. C., Sept. 7, 1827, and died in Cleveland, Ohio, in his sixty-first year, March 25, 1888. He traced his descent from the English martyr, Bishop Hugh Latimer, after whom his son was named.

Mr. Latimer was appointed a cadet in the U. S. Naval Academy at

Annapolis at the age of fourteen, graduated from there with credit and remained in the government naval service in all about thirteen years, one year of which as assistant professor at the Naval Academy and the remainder chiefly in sea service.

When the war broke out, Mr. Latimer promptly and unhesitatingly joined the Union forces, although of Southern parentage and residence, and served the government with zeal and enthusiasm, most prominently as an assistant engineer in the U. S. military railway service. His military activity ended in 1864-5. During this period, in connection with his previous experience as a naval officer, the foundation was undoubtedly laid for Mr. Latimer's most remarkable trait, his notable executive ability in the selection and management of men.

At different periods Mr. Latimer devoted himself to steamboat service, but it was in connection with railroad work, for many years, that his name became so well and favorably known, both inside and out of the engineering profession. His career in this branch commenced in 1854, when he was 27 years old. He was at different times connected with several different railroad corporations, and with either of these, and in all instances, his services were appreciated and recognized, as indicated by never-failing rapid promotions.

The corporation with which Mr. Latimer was most prominently identified, and for by far the longest space of time, was the New York, Pennsylvania & Ohio Railroad. By successive stages he reached the position of Chief Engineer for that road, in 1874, and which he held constantly until March, 1886, when the consolidation of the road with the Erie, and a consequent change of management, caused him to resign.

He was then offered the position of Consulting Engineer, or Engineer for the lessor company, which he accepted and held to the day of his death.

The so well known and extremely valuable invention, the "Latimer Rerailing Guard," was the product of Mr. Latimer's brain. It was made in 1871, and is almost universally approved and very extensively used.

Mr. Latimer was very widely known to persons of almost all classes and conditions by his enthusiastic belief and interest in what he called the "divining rod," and in the construction of the pyramids by divine inspiration, basing upon the latter theory the firm conviction that an abandonment of the English weights and measures, clearly defined in the pyramids, as he claimed, would be positively sacrilegious. Those who cannot join in these views (and beliefs) must, nevertheless, confess to a feeling of admiration and respect for the genuine sincerity and ardent zeal wherewith he advocated these his pet tenets, and may we not willingly agree that what we cannot disprove we should not contradict?

Mr. Latimer was recognized as being truly and sincerely religious, not merely in the attendance of the regular service in the church but in the daily walks of life and in his dealings with his fellow men, and he was in consequence loved and respected by all who knew him.

Mr. Latimer was a member of the American Society of Civil Engineers and of the Civil Engineers' Club of Cleveland, as well as of our society, of which he became a member February 10, 1873. Being a non-resident of this city, he was but seldom seen at our meetings, and was

not, on that account, as well known *personally* to the members of this society as he was *professionally* known to the engineering profession at large.

Mr. Latimer was married, in 1866, to a Miss Lombard, of this State, who made him a devoted and loving wife, and by whom he had four children, three daughters and one son, who survive him. Mrs. Latimer died in 1875.

The following eloquent tribute to Mr. W. L. Baker, of Detroit, Mich., has been written by one of intimate association :

W. L. BAKER, OF DETROIT, MICH. DIED MAY 28, 1888.

William L. Baker was born at Toledo, O., June 16, 1850. He was the eldest son of William Baker, the well-known lawyer of that city. He early developed a liking for mechanical and mathematical studies, and his education was naturally turned in that direction. He passed through the Polytechnic Institute at Troy, N. Y., being graduated in 1871. He immediately engaged in active professional duty, serving as Assistant Engineer in the construction of the bridge then being built across the Mississippi River at Hannibal, Mo., and subsequently of the bridge over the Missouri River at St. Joseph, Mo. The interest that he took in these enterprises and the capacity that he exhibited showed that his natural tendency was toward bridge engineering, and in 1872 he took service with the Detroit Bridge and Iron Works, of Detroit, Mich. Here he found congenial duty, and his life work was done. Commencing in a subordinate position, he developed such fidelity and capacity that promotion naturally followed, and he was advanced from rank to rank until he finally became Engineer and Superintendent of the entire establishment. He loved his work, and always found in it his chief pleasure, for there was room and opportunity therein for the development of his best faculties. The establishment with which he was connected has been for the last twenty-five years largely engaged in engineering construction, and to Mr. Baker is due much of the credit for its success. No one can ride over the great railways of the Northwest without passing over many iron bridges which were designed and built under his supervision. They bear silent witness to his professional capacity and honesty.

In addition to being an excellent technical engineer, he was also a good executive officer and manager. He was a man of affairs, a good judge of men, was keen-sighted and quick-witted, and capable of recognizing and appreciating merit in his subordinates. He instinctively gained the respect and liking of his men, and they were naturally true and loyal to him. He was honest in his work, and while he always sought economy he never allowed scamping. He insisted on thoroughness and fidelity in the execution of contracts, and no one ever knew him to wink at or permit slackness or inferiority of work.

Added to this high professional character he was by nature a genial, kindly gentleman. Of winning manners and pleasant address, every one that knew him liked him. Hosts of friends all over the country mourn his untimely taking off.

About two years ago his health began to fail. His characteristic pluck

and energy showed itself in the way he fought growing weakness and distress. Last fall he went abroad for a few months, hoping relief by rest and recreation. But it was in vain, and he returned no better than he went. His physical ailings finally terminated in consumption of the lungs, and the end came May 28, 1888. He died peacefully at his home in Detroit, surrounded by his family and friends, and when he quietly sank into the great final rest many fond loving hearts were sorely stricken.

He became a member of our Society of Civil Engineers, November 10, 1873. Although his residence at Detroit was so far from the headquarters at Chicago that he could not often attend our meetings, yet he was known to most of the members. And we as individuals as well as a society feel that in his death we have sustained a great loss.

He was married in 1879 to Miss Kate Mead, of Lockport, N. Y., who, with two children, survive him.

He died at the early age of 38 years. His career, which ought to have been just opening, was untimely shortened. Life was fair and bright and hopeful before him—but the end came. We can only bow our heads in humble silence under such mysterious Providence.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

OCTOBER 17, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 19:30 o'clock, President FitzGerald in the chair, thirty-nine Members and ten visitors present.

The record of the last meeting was read and approved.

Messrs. Edgar P. Sellew and Charles W. S. Seymour were elected Members of the Society.

The following were proposed for membership :

Frank A. McInnes, of Dorchester, Mass., recommended by Sidney Smith and M. T. Cook; J. Parker Snow, of Somerville, Mass., recommended by S. E. Tinkham and J. E. Cheney; and J. Frank Williams, of Lynn, Mass., recommended by M. M. Tidd and W. A. Favor.

On motion of Mr. Hammatt, it was voted, That the thanks of the Society be extended to Mr. J. Pickering Putnam, for the very interesting paper read at the last meeting.

On motion of Mr. Howe, the Secretary was requested to acknowledge in the name of the Society, its appreciation of the attention received from Mr. George H. Norman on the occasion of the excursion to Newport, also its appreciation of the courtesies received from Messrs. Shields and Carroll on the occasion of the visit to Harvard Bridge.

Mr. Swan offered the following motion, which was adopted: Whereas, the clock which was recently presented to the Society is arranged in the twenty-four hour system, that, as an experiment, the Secretary be authorized to use the twenty-four hour system in the notices of the Society until otherwise instructed by the Society.

On motion of the Librarian, the sum of \$65 was appropriated for the renewal of subscriptions to periodicals and for binding.

The first paper of the evening, entitled "Construction of Farm Pond Conduit," by Henry H. Carter, was then read by Mr. Stearns in the absence of the author, and was discussed by the President and Messrs. Folsom, Hall, Smith and Stearns.

Mr. Richard A. Hale exhibited a Berrenburg Rotary Pump, and read a paper giving the results of a test made by him of its efficiency.

Mr. Frederick Brooks read portions of a paper prepared by him on "Time Reform," with special reference to the twenty-four hour system of reckoning time.

[Adjourned.]

S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

OCTOBER 10, 1888:—The 251st meeting was held, Mr. S. G. Artinngstall in the chair.

The minutes of last meeting were approved.

Mr. Levis Passmore Pennypacker, Assistant Engineer U. S. Construction Company, Chicago, Ill., was proposed for membership.

The resignation of Mr. C. F. Carl Binder, of Cleveland, who proposed to join the Cleveland Society, was received.

The following financial exhibit is compiled from reports of Secretary and Treas-

urer: Receipts since last meeting, \$49.50; cash on hand, \$107.82; bills paid, \$30; bills reported, \$240.50.

The Secretary presented written discussions of Mr. Wisner's paper upon "Levels of the Lakes as Affected by the Proposed Lake Michigan and Mississippi Waterway" from the following parties:

Prof. F. M. Haupt, of Philadelphia; Mr. Clemens Herschel, of Holyoke, Mass.; Prof. J. B. Johnson, of St. Louis, Mo.; William Pierson Judson, of Oswego, N. Y.; Walter P. Rice, of Cleveland, O., and D. Farrand Henry, of Detroit, Mich. These papers were read and discussed and the Secretary authorized to compile the same with suitable explanatory matter for publication. It was announced that other contributions were expected.

[*Adjourned.*]

L. E. COOLEY, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

OCTOBER 1, 1888:—The October meeting of the Society was held at the Hotel Ryan, President Loweth in the chair; 12 Members present.

Upon ballot Mr. J. D. White, City Engineer of Fargo, was elected Member of the Society.

The form of contract for buildings as recommended by the National Association of Builders was brought up for discussion but laid over to the next meeting of the Society.

A paper was read, prepared by the President, upon some tests of angle bars made by him in 1887, the results of which tend to give information upon the influence of rivets and rivet holes in such members. The paper was illustrated with drawings showing members tested and the fractures.

Mr. A. Münster followed with a paper upon "The Highways and Railroads of Norway." Mr. Münster gave an interesting sketch of the general topographical features of Norway and then described the national wagon roads and the railroad system. The paper was illustrated with plans of the more important bridges and photographs of the scenery along the railroads. The views showed some examples of striking railroad location and gave some fine pictures of the country.

[*Adjourned.*]

GEO. L. WILSON, Sec'y.

ENGINEERS' CLUB OF KANSAS CITY.

OCTOBER 1, 1888:—Regular meeting held in Y. M. C. A. building, President Knight in the chair; 14 Members and 5 visitors present.

Minutes of the previous regular and executive committee meetings were read and approved.

On a canvas of ballots, John M. Walker, S. H. Yonge and H. H. Filley, were declared elected as members, and S. P. Maybach as Associate Member.

The Secretary announced that arrangements had been completed, by which the Club would have the exclusive use of a small furnished room in the Y. M. C. A. building for a library, and of the adjoining two rooms of Prof. Fulton for meetings the first and third Mondays of each month for \$15 per month.

It was stated that papers had been promised for nearly every meeting up to March.

A letter from Mr. C. R. Taylor, of Philadelphia, was read, describing a new patent for street pavements.

Proceedings of the American Society of Civil Engineers and New England Water-Works Association had been received for the library, and Mr. G. W. Pearsons promised a set of the proceedings National Water-Works Association.

Mr. A. J. Mason read a paper entitled "The Complete Sewerage of Kansas

City," which was discussed by Messrs. G. W. Pearsons, Gillham, Knight, Kiersted and Allen.

C. S. Clarke was proposed as Associate Member by W. D. Jenkins and B. L. Marsteller.

[Adjourned.]

KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

OCTOBER 20, 1888:—The regular monthly meeting was held at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Railroad, at 7:30 P. M., Mr. Beckler, Second Vice-President, in the chair. Those present were Messrs. Haven, Beckler, Kelly, Farmer, Herron, Foss, Ellison, Goodridge and Keerl.

The written application of F. J. Smith for membership in the Society was received and ordered filed, to be acted upon through letter ballot. Application endorsed by Messrs. Herron, Ellison, Foss and Farmer.

Messrs. Geo. A. Foss, J. H. Farmer and John Herron were appointed a Committee upon Highway Bridges, to act in conjunction with similar committees of other societies, who are to endeavor to promote the movement looking to a reform in the matter of highway bridges.

The Librarian reported having been in correspondence with officers of the *Railroad Gazette* relative to securing for the Library of the Society the back numbers of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. He stated that while the early volumes of the JOURNAL were scarce, the Society now had the opportunity of securing the complete set, and as he deemed it would be a most valuable acquisition to the library, he hoped the Society would determine upon their purchase. On motion, carried unanimously, the Secretary was instructed to secure for the Society's library all the back numbers of said JOURNAL, and to ascertain to what extent and at what cost the numbers from 1 to 5, inclusive, of the current volume can be furnished members who may desire to secure the complete volume.

The chair read a letter from Col. J. T. Dodge, relative to his removal from Montana, and his desire to withdraw from active membership, as provided by Art. IV., Sec. 5, of the By-Laws. On motion, carried, the withdrawal of Col. J. T. Dodge from active membership was allowed.

On motion, carried, that the Nominating Committee, as provided by Art. V. Sec. 3 of the Amendments to the Constitution, shall be elected by the meeting—the following were placed in nomination for such Committee: Messrs. W. A. Haven, John Gillie and A. E. Cumming, and, upon motion carried, were declared elected.

The Chair called the attention of the meeting to the dangerous crossing of Main street at Sixth avenue in the City of Helena, as proposed by the Motor line, suggesting the subject as a proper one for discussion by the Society.

Mr. J. H. Farmer, Chief Engineer of the Motor line, stated the grade and alignment of streets at the proposed crossing, upon which data the meeting entered into a general discussion at some length of the feasibility and the advisability of the Motor line bridging Main street, that street being approached from either side by steep descending grades. The paper for the evening precluding further time being given to this discussion, Messrs. W. A. Haven, Geo. O. Foss and E. H. Beckler were appointed a Committee to consider and report at the next meeting upon an overhead crossing for the Motor line at Main street and Sixth avenue.

Mr. E. O. Goodridge, engineer in charge of the north end of the Wickes Tunnel on the line of the Montana Central Railway, read a paper upon the "Ingersoll Rock Drill," illustrating the same with sectional drawings. After describing the

drill in detail, Mr. Goodridge entered upon a general description of the work it had accomplished at the Wickes tunnel, but recently finished.

After a discussion of the paper at some length it was on motion referred to the "Committee on Topics" for report at the next meeting upon the advisability of its publication.

The communication from Mr. Geo. O. Foss, relative to the difficulties encountered in endeavoring to define the locus and ownership of mineral locations from County Recorders' records, was upon motion returned Mr. Foss with the request that he present a paper upon this subject at the next annual meeting of the Society.

Meeting adjourned to meet November 17th next at same time and place.

J. S. KEERL, Secretary

INDEX DEPARTMENT.

In this department is given as complete an Index as may be of current engineering literature of a fragmentary character. A short note is appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. It is printed on but one side of the paper, so that the titles may be cut out and pasted on a card or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

Address, Annual, to the Engineers' Club of Philadelphia. By T. M. Cleemann, retiring President. Gives a comparison of the growth of engineering societies and a brief review of the work Philadelphia and Pennsylvania have accomplished. *Proc. Engrs. Club, Philadelphia*, Vol. VI., pp. 225-234 (Feb., 1888).

Address to the Mechanical Science Section of the British Association, Bath, 1888. By W. H. Preece, President of the section. Reviews the developments of the practical applications of electricity. *Engineer*, Sept. 7, 1888; *T. J. and Elec. Rev.*, Sept. 7, 1888; *Jour. Soc. Arts*, Sept. 14, 1888; *Sci. Am. Supple.*, Sept. 29, 1888.

Aluminum Influence upon Cast Iron. By W. J. Keep, Prof. C. F. Mabery and L. D. Voice before the American Association for the Advancement of Science. A valuable paper, giving details of experiments made to determine the effects of aluminum on cast iron. Good results were obtained by its use. *Sci. Am. Supple.*, Sept. 8, 1888.

Aqueduct, Croton, Method of Detecting Bad Work. Gives a brief description of the methods employed to detect and repair the bad work on the Croton Aqueduct. *Engr. News*, Oct. 13, 1888.

Boilers, Circulation in. See Locomotives.

Bridge, Chenab, India. Gives two pages of detailed drawing and abstracts from the specifications of the Chenab bridge, India state railroads. It is composed of 17 spans, of 206 feet each, of riveted triangulated girder. *Engineer*, Sept. 14, 1888.

—, *Forth.* By F. E. Cooper, before the Iron and Steel Institute. Gives a general description of the methods employed in the erection of the various portions of the main span. Abstracts in *Engineer*, Aug. 24, 1884; *Engr. News*, Sept. 22, 1888; *Sci. Am. Supple.*, Oct. 13, 1888.

—, *River Ouse, Bedford, Eng.* Gives plan, elevation and cross-section of a foot-bridge of 100 ft. span, practically without abutment. *Sci. Am. Supple.*, Sept. 8, 1888.

—, *Petaluma Draw.* Gives brief description, with general view and plan and elevation, of the central pier of the Petaluma draw-bridge on the San Francisco & North Pacific Railroad. *Engr. News*, Oct. 13, 1888.

—, *Pony Lattice, W. S. R. R.* Gives plan, elevation and cross-section, with dimensions of a pony lattice bridge truss built at Normanskill, N. Y., on the West Shore Railroad. Span, 86 ft.; clear width, 14 ft.; height, 10 ft., and weight, 50 tons. *R. R. Gazette*, Sept. 21, 1888.

—, *Failures.* By G. H. Thomson, before the Bath meeting of the British Association. Discusses bridge failures and their causes, and details of experiments made on various types of bridges. *R. R. Gazette*, Sept. 28, 1888.

Car, 50,000-lb. Box, C., B. & Q. R. R. Gives plan, elevation and cross-sections, with full dimensions of the 50,000-lb. box-car in use on the Chicago, Burlington & Quincy Railroad. *Master Mechanic*, October, 1888.

BOOKS FOR ENGINEERS.

THE DRAINAGE of Fens and Low Lands by Gravitation and Steam Power. By W. H. Wheeler, M. Inst. C. E. 175 pages, illustrated by 8 folding plates, 8vo, cloth. Price, \$4.00.

PRACTICAL NOTES on Pipe Founding. By James W. Macfarlane. Giving practical details of the manufacture of cast-iron pipes from 16 to 48 inches diameter in 12 feet lengths. 148 pages, with 16 plates, 8vo, cloth. \$4.00.

A PRACTICAL TREATISE on the Strength of Materials, Including their Elasticity and Resistance to Impact. By Thomas Box. 527 pages, with 27 plates. Crown, 8vo, cloth. \$7.25.

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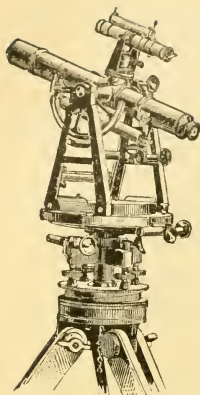
- Canal, Manchester Ship, Plant and Machinery.** By L. B. Wells, before the Bath meeting British Association. Gives a brief description of the principal machinery now in use on the Manchester Ship Canal. *Engineer*, Sept. 21, 1888.
- , *Tancarville, France.* Gives brief description of the canal being constructed between Havre and the Seine. *Sci. Am. Supple.*, Sept. 15, 1888.
- Canal Lift, Fontinettes, France.** Gives a discussion on canal lifts *vs.* locks, and a description, with view, of the hydraulic lift at Fontinettes, France. *R. R. Gazette*, Sept. 21, 1888; *Engr. & Mining Jour.*, Sept. 29, 1888.
- Cements, Hardening of.** A series of articles embodying the results obtained in the most recent and important investigation on the hardening of cements. The subject is treated from a chemical point of view. *Engineer*, Sept. 21 *et seq.*, 1888.
- Contract, Standard Building.** Gives text of a standard building contract, the adoption of which is advised by the Committee of Conference of the American Institute of Architects, the Western Association of Architects and the National Association of Builders. *Engin. & Build. Rec.*, Sept. 15, 1888.
- Dam, Gileppe.** By A. Marichal. Gives a brief description of the curved masonry dam near Verviers, Belgium. Illustrated. *Proc. Engr. Club, Philadelphia*, Vol. VI., pp. 243-246.
- , *Quaker Bridge.* Gives an abstract from the report of a Board of Experts on the Quaker Bridge dam. *R. R. Gazette*, Oct. 12, 1888.
- Drawings, Cyanotype Process of Reproducing.** Gives notes compiled in the Photographic Office Survey of India Department, Calcutta, on the positive cyanotype process of reproducing drawings with dark lines on a clear ground. *Indian Engineering*, Aug. 4, 1888.
- Dynamo Machines, A Synthetic Study of.** A series of articles giving a full synthetic study of dynamo machines, including a good exposition of induction. *T. J. and Elec. Rev.*, Aug. 3, 1888.
- Electric Lighting Installation Breakdowns.** By R. F. Jones, before the Old Students' Association, Finsbury Technical School. Gives a classification of breakdowns in electric plants; then gives actual cases, with their symptoms, causes and cures. *El. Jour. & Elec. Rev.*, June 22.
- , *Installation, "Kaiser Gallerie," Berlin.* Gives description of the plant at the King's Gallery, Berlin, with a two-paged plate showing plan and section of engine room. *Engineer*, Sept. 21, 1888.
- Electric Motors. Charges for Services.** A paper presented to the Electric Light Convention, showing that there is a general average controlling the use of machinery which is safe for power companies to follow in making charges for electric motors. *Sci. Am. Supple.*, Sept. 22, 1888.
- , *Notes on the Governing of.* By W. E. Ayrtton and J. Perry, before the Physical Society. *T. J. and Elec. Review*, July 29, 1888.
- Electric Railroads.** By T. J. Sprague, before the American Institute of Electrical Engineers. A valuable and exhaustive paper, covering the whole field of electric railroads; also contains a description of the Richmond line, with detailed account of daily working expenses. Abstracted *T. J. and Elec. Rev.*, August 3, 1888.
- Engine, Efficiency of Plant.** By Prof. De Volsen Wood. A review of the recent steam engine efficiency. *Sci. Am. Supple.*, Sept. 1, 1888.
- , *Marine, First Century of the.* By Prof. H. Dyer, before the Institution of Naval Architects. Gives a brief *résumé* of the chief steps in the development of the steam engine and marine navigation. *Engineer*, Sept. 21 and 28, 1888.
- Friction of Metal Coils.** By Prof. Hele Shaw and Edward Shaw, before the Bath meeting of the British Association. *Engineer*, Sept. 23, 1888.
- , *Clutches.* By Geo. Adams. A practical paper on the construction of friction clutches. Illustrated. *Engineer*, Sept. 7, 1888.
- Frictional Gearing on a Dredge.** By J. G. Griffith, before the Institution of Mechanical Engineers. Gives a description of the frictional gearing used on a double steam dredge in the port of Dublin. Illustrated. *Engineer*, Aug. 24, 1888.

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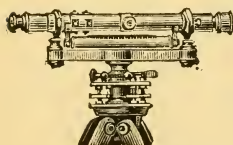
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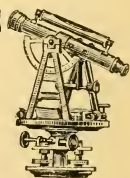
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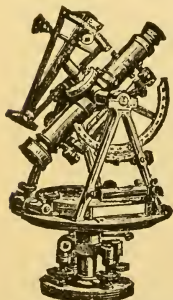
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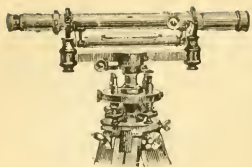
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INDEX DEPARTMENT.

- Furnaces, Safe Working Cylindrical Pressures for.** By M. Langridge. Discusses the different formulæ relating to the safe working pressure on cylindrical furnaces and flues, showing their discrepancies, and proposed a modified form of Fairbairn's formula. *Engineer*, Sept. 21, 1888.
- Gas. Loomis Fuel Gas Plant.** Gives brief description of the Loomis fuel gas plant at Tacony, Pa., with account of the Loomis system of production. *Amer. Manufacturer*, Oct. 5, 1888.
- Gas Holders Without Upper Guide Frames.** By T. Newbegg, before the Manchester District Institution of Gas Engineers. Describes a method of constructing gas-boilers with inclined guides at the base, constructed in such a manner as to do away with a large part of the upper frames. *Engineer*, Sept. 14, 1888.
- Harbor, Improvement of New York.** Gives a brief description of the centrifugal pumps in use on the excavator in New York harbor. *Sci. Am. Supple.*, Aug. 25, 1888.
- Inland Navigation in Germany.** See Railways and Waterways.
- Iron, Rusting of.** By A. C. Brown, before the Edinburgh meeting of the Iron and Steel Institute. Explains the process involved in the rusting of iron. *Am. Engr.*, Sept. 26, 1888; *Master. Mech.*, October, 1888; *Engineer*, Sept. 2, 1888.
- Liquid Fuel for Gas Retorts.** Gives details of experiments made on burning coal tar under gas retorts with the Drury spray nozzles. Illustrated. *Engineer*, Sept 7, 1888.
- Locomotive. Circulation in Boilers.** By John Hickey, before the Western Railway Club. Discusses the proper construction of locomotive boilers and fire-boxes to obtain the most economic results. *Master Mechanic*, October, 1888.
- Mechanical Engineers, Advice to Young.** By Prof. Perry to the students at Finsbury Technical College. A valuable paper for working engineers. *Sci. Am. Sup.*, Sept. 1, 1888.
- Paving, Valuation of Road Metal and Setts for.** By W. F. Stock. Discusses the salient features to be looked at in selecting road material, and gives results of examinations made with a machine for testing the abrasion resistance of road metal. *Eng. News*, Sept. 22, 1888.
- Pipe, Strength of a Copper Steam.** Gives an abstract from a report for the Board of Trade Surveyors on the testing of a copper steam pipe taken from a steamship. *Engineering*, Sept. 14, 1888.
- Planimeter, New Spherical.** By Prof. Hele Shaw. Gives an illustrated description, with theory of action, of a new spherical planimeter. *Engineering News*, Oct. 13, 1888.
- Propulsion of Ships by Air Propellers.** By H. Vogt before the Bath Meeting of the British Association. Gives details of experiments made with propellers working in the air instead of the water. *Engineer*, Sept. 28, 1888.
- Railroads. Ratio of Population to Mileage.** By W. H. White. Gives diagram showing the ratio of population to railroad mileage, and the probable increase of mileage demanded. *R. R. Gazette*, Oct. 5, 1888.
- . **Rolling-Stock and Tramways, Guinness Brewery.** By S. Geoghegan, before the Institute of Mechanical Engineers. Gives a full description, with detailed drawing, of the rolling-stock and tramways at a brewery in Dublin. *Engineer*, Aug. 31, 1888.
- Railroad Construction, Notes on.** By Theo. Low. Give hints which may be of use to young assistant engineers on construction work. *Proc. Engrs. Club, Philadelphia*, vol. V., pp. 236-242 (February, 1883).
- Railroad and Waterways, Relative Advantages of, in Germany.** By M. Todt. A valuable paper giving statistics relative to the quantities of goods carried in Germany by rail and by water, ratio of tons to population, etc.; also discusses the relative advantages of the railroads and waterways. Translated from the *Bulletin du Ministère des Travaux Publics for the Journal of the Royal Statistical Society*, July, 1888. Abstracted. *Jour. Soc. Arts*, Aug. 31, 1888.



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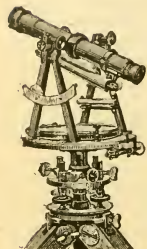
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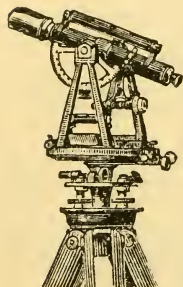
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- Reservoir, New Storage, Grand Junction Company, Earling, Eng.** Gives brief description, with plan, cross sections, elevations, etc., of a new storage reservoir, of a capacity of 51,000,000 gallons, constructed for the Grand Junction Waterworks Company, Earling, England. *Engineer*, Aug. 24, 1888.
- Road Metal and Paving Setts, Valuation of.** By W. F. K. Stack. Discusses the proper method of testing road-making material, and gives details of tests made on duration by means of a machine. Illustrated. *Engineer*, Aug. 31, 1888.
- Roof Truss, Depot of the Central Railroad of New Jersey.** Gives plan and elevation of the new depot of Jersey Central Railroad at Communipaw, etc., also half-section showing roof truss, with dimensions. Its span is 142 feet. *Engin. News*, October 6, 1888.
- Steel, Influence of Copper on Tensile Strength.** A paper prepared by E. J. Ball and A. Wingham for the Iron and Steel Institute. Gives results of experiments made to ascertain the effect of copper on the tensile strength of steel and iron. It appears to render them extremely hard. *Amer. Manufacturer*, September 28, 1888.
- Transit Notes, Best Method of Keeping.** Gives a number of articles on the best method of keeping transit notes of curves. *Engin. News*, September 22, *et seq.*
- Transmission of Power, Electrical.** By Prof. Ayrton, before the Bath meeting of the British Association. Discusses the advantages of electrical transmission of power, and tells what is being done. *T. J. and Elec. Rev.*, Sept. 21, 1888; *Am. Eng.*, Oct. 3, *et seq.*, 1888.
- Town Refuse, Destruction of.** By Thomas Codrington. Gives a report on the different methods in use for destroying town refuse. Contains large amount of data relating to refuse. Abstracted *Eng. and Build. Record*, Sept. 15, 1888.
- Garbage, Disposal of.** See Town Refuse.
- Water Pipes, Cast Iron.** Gives a table of dimensions of cast-iron water pipes as derived from the practice of an experienced engineer. *Mech. World*, Sept. 22, 1888.
- Water Supply, Stand Pipes.** By B. T. Stevens before the American Waterworks Association. A valuable paper, giving details of a large number of stand pipes. It also gives practical suggestions on their construction and details of a number of failures. *Engr. News*, Oct. 6, 1888.
- Water-Works, Denver.** By S. Fortier. Gives a full description of the waterworks of Denver, with drawings of many of the details of construction. *Engin. News*, Sept. 22-29, 1888.
- , **Minneapolis Pumps.** Gives a brief illustrated description of the pumps in use at the Minneapolis water-works. *Engin. and Build. Rec.*, Sept. 15, 1888.

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THE DAM OF THE CAMBRIDGE WATER-WORKS ON STONY BROOK.

BY WILLIAM S. BARBOUR, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

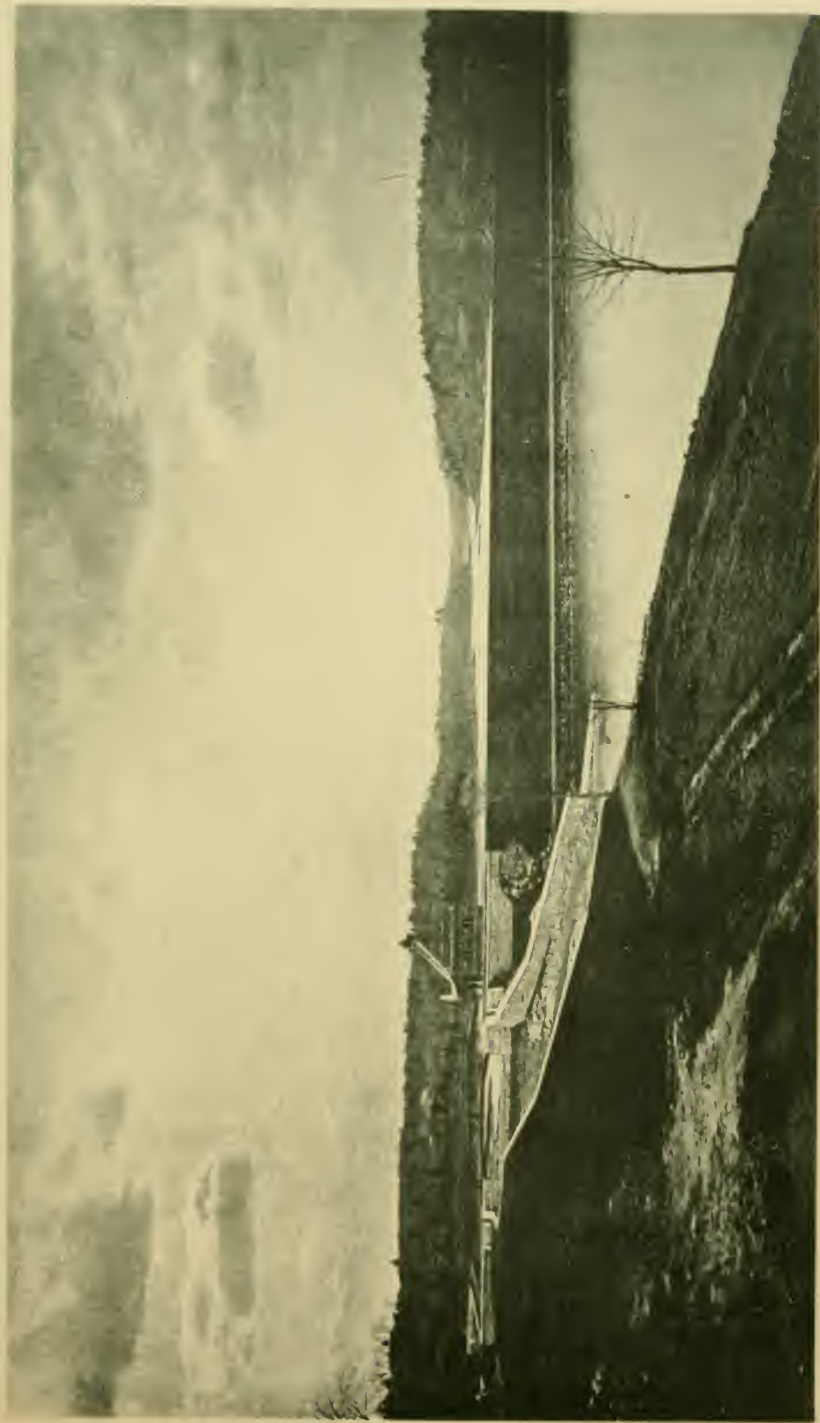
[Read June 20, 1888.]

Having been invited by your President, I have prepared some notes describing the work at the dam and basin at Stony Brook, recently built for the Cambridge Water-Works; also some of the difficulties encountered and the methods adopted to overcome them.

The location of the new supply lies partly in Waltham and partly in Weston, and is known as the Stony Brook supply. It is nearly eight miles from Fresh Pond, which is connected by a line of 36 and 30-inch pipe.

The source of Stony Brook is Sandy Pond in Lincoln. There are numerous other branches, among them the Hobbs Brook, quite, if not equally, as large as Stony Brook, with its source in Lexington, Cherry and other brooks without names, the whole draining a territory covering an extent of about 21 square miles. After the surveys were made and temporary locations for the site of the dam were selected, lines of borings were made to determine the precise nature of the bottom on which the dam was to be erected, and also the best and most favorable site. You will observe that this was very important, as all the future work was dependent upon a careful and judicious selection of the site. Two kinds of borings were made. The first by driving a one and one-half inch iron tube with heavy weights, then washing out the material from inside the tube with water forced down with a force pump, through a smaller tube inserted in the larger, the water flowing out of the larger tube and bringing up the material with it. The other method was sinking a tube of 5 inches diameter, the interior of core being removed with a sand pump. Samples of all the above described borings were collected, placed in glass tubes and kept for comparison, and upon which the final character of the foundation was adopted. The results of the borings, which were carried down to a depth of, in places, 75 or 80 feet below the bed of the stream, revealed the unwelcome fact that the underlying strata below the surface crust, which was from 4 to 22 feet in thickness, was a bed of very fine sand extending to a great depth, a very undesirable and dif-

ficult substance to build a dam upon. This surface crust was very uneven, and it was decided to be necessary to go through it to the sand bed and drive sheet piling into the sand as deep as it was possible. The size of the sheet piling adopted was 8 inches thick and of varying lengths of from 10 to 30 feet, with tongues or splines $1\frac{1}{2}$ by 3 inches in width. As this piling was very heavy and probably the largest and heaviest ever driven in this vicinity, it became necessary to provide special machinery for driving it. The contract was so drawn as to provide, if necessary, a steam hammer and the use of a water jet if required. A steam pile hammer, made by the Cram Brothers of Detroit, was at last found which it seemed would fill the requirements of the case, and one was secured by the contractor for this work. Its weight was 5,500 pounds, with stroke of 40 inches capable of being run 75 to 100 blows per minute. The ordinary and actual use made in practice was 60 to 75. The hammer worked in an iron frame about 8 feet long, which in turn was fitted to slide up and down in the gins of an ordinary pile driving machine. Steam was supplied through a flexible hose from boiler standing on the bed frame of the machine. The operation of driving was as follows: The pile being hoisted into the gins, the frame and hammer being raised sufficiently high to receive it, the frame was then lowered on the head of the pile, the bottom of the pile being secured between guides in the usual manner, and properly dogged and wedged, the point of the pile being sharpened so as to hug up and shod with wrought iron plate bent to fit, the driving was commenced, the blow being transmitted through a short follower about 18 or 20 inches long. The followers were used up quite rapidly as the blows were rained thick and fast upon them, the pile in scarcely any case moving more than $\frac{1}{2}$ to $\frac{3}{4}$ of an inch to a blow. The sand was very hard to drive into, and when dry or free from water was almost as hard as a rock; attempts made to drive into it without shoeing with iron, made sorry work of it, the bottom of the pile being broomed up for 5 or 6 feet so as to appear like a bundle of pack-thread. Other difficulties and obstructions were encountered, such as boulders and streaks of hard pan, some of which had to be dug out by going to considerable depths. The use of the water jet in connection with the driving proved exceedingly useful in cases when in driving, the sand being dry, would become so compact that no amount of pounding with the hammer would move the pile; then the water jet, which consisted of a stream of water under pressure through a hose to which an iron pipe $\frac{1}{2}$ inch in diameter and about 20 feet long was attached, would be run down along side of the pile, the force of the water escaping at the open end of the tube loosening up the sand and opening a way for the pile, which would then start quite easily under the blows of the hammer. Then sometimes a boulder would be in the path of the pile, and stop its progress. The jet would then be put down a little way outside of the stone, forming an opening by washing away the sand, and allowing the stone to roll away into the hole formed and leaving a free passage for the pile. Many difficulties and discouragements were encountered, and there were times in the progress of this part of the work when it seriously looked as though the sheet piling would have to

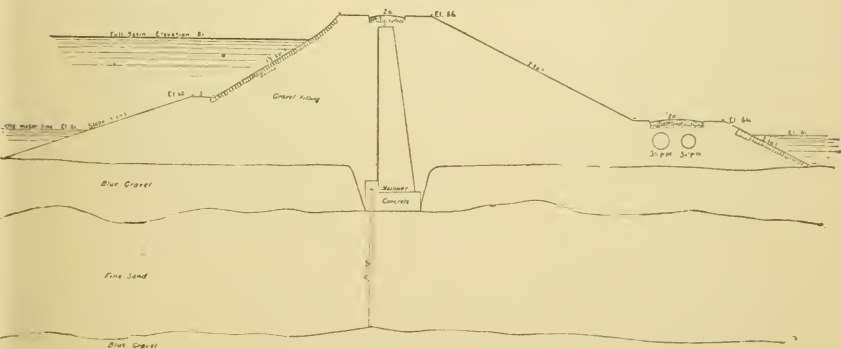


HELOISE B. NETE 201

STONY BROOK DAM.

STONY BROOK

be abandoned. At first the men in charge of the machine, not being accustomed to it, did not understand how to run it, and the packing from the steam joints was frequently blown out. An urgent letter to the inventor of the machine stating that if he desired his machine to be a success in these parts he must come on and instruct us how to use it was promptly heeded, and our men soon became familiar with it. At another time the difficulties were so great that the contractors refused entirely to go on, saying it was an impossibility to drive the piles. Feeling the great importance of this part of the work, the machine and gang were taken in hand by the engineers and inspector, the work carried on by day labor, until the obstructions, after much patient labor and persistence, were overcome, and the fact demonstrated that patience and perseverance would accomplish this work (and also at an expense not exceeding the contractor's prices). The machine was again taken in charge by the contractor, and from this time the work proceeded regularly, though at times very slowly, and there now exists a tightly driven row of sheet piling extending the entire length of the foundation of the dam, some 650 feet. Where the hard bottom came within 30 feet of the surface of the sand, they were driven into it; and where not, they were driven about 30 feet—an extraordinary and difficult thing to do, and, so far as the writer is aware, was never before accomplished in this vicinity with sheet piling of such length and thickness. After the piling was in place the tops were cut off to near the level of the sand, and were inclosed in a bed of concrete 12 feet wide and 4 feet thick, stepped down at intervals to conform to the varying depths of the trench. Upon this



Section of Stony Brook Dam.

base of concrete there was erected a core wall, 8 feet in thickness at the bottom, brought up to about the natural level of the bottom of the old pond, and from this level to 3 feet below the top of the dam, battering on the down stream side to 3 feet in thickness. This wall was composed of two thin walls, one on each side, laid with stones of large size obtained from the basin and vicinity, laid solid in cement with the space between these walls filled with small stones placed in layers not exceeding one foot in thickness, the interstices between being filled with grout or liquid cement. The up-stream face of this wall was smoothly plastered with clear cement. This wall in the highest part measures 50 feet. It was

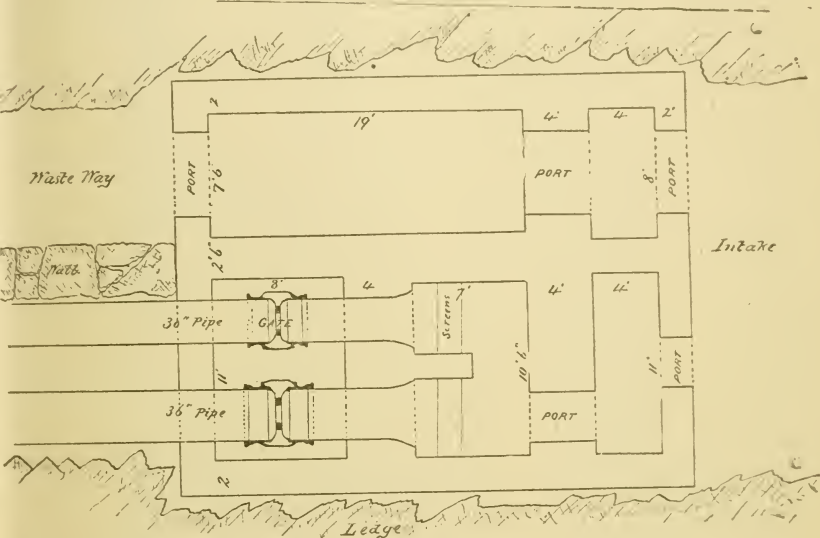
feared by some that from its great height and its resting on a bed of sand that it might settle and crack. An iron pipe was inserted in the foundation and carried up on the outside of the wall to the top, upon which levels were taken from time to time. As yet no settlement has occurred, and it is now thought that all danger on that score has passed. As the wall was completed the remaining portion of the trench was filled with selected material carefully puddled and tamped with heavy rammers, or rolled with grooved rollers. The earthwork of the dam will average about 180 feet thick at the base and was carried up in layers of selected material (all stones greater than 3 inches in diameter being excluded) not exceeding one foot in thickness, thoroughly wet and rolled with loose wheeled sectional rollers to a thickness of about 6 inches. At elevation 64.00, there is a berme on the lower side 20 feet wide, and at 68.00 one on the upper side by which the base is reduced to 96 feet. The outer face is carried up with a slope of 2 horizontal to 1 vertical and is covered with loam and sodded in part and seeded. The up stream side, to the level of the berme is carried up with a slope of 3 to 1, and from this level is made $1\frac{1}{2}$ to 1, with a slight curve at the top to prevent the wave action from washing the top of the dam. The whole face of the up stream side is paved with heavy field stone 18 inches thick laid on a bed of small or cracked stone. The top of the dam is 20 feet wide and has a walk in the centre 8 feet in width, while the borders are covered with loam and seeded. The north end of the dam was entered into the bluff about 50 to 75 feet, the up stream side being turned with a curve of 100 feet radius, thus lapping well on to the up stream side of the bluff. A curve was also made on the down stream side, thus making the thickness at this point more than double that at any other; this, owing to the porous nature of the natural hill, was thought necessary.

At the southerly end of the dam a much better state of things existed, the material there being ledge, and opportunity was taken to locate there all the appurtenances for collecting, distributing and wasting the water, for which ample provision has been made. A channel 30 feet wide and about the same depth was first blasted out and the gate chamber afterwards located in the excavation about in line with the centre of the dam.

The chamber is built of cut stone, being largely of granite from Keene and Mason, N. H., laid in courses of about 2 feet rise each, the exterior faces being quarry faced, with arris lines around the edges of each stone. The chamber is divided into five smaller chambers, by heavy partition walls all of cut stone, and for the following uses: The right hand up stream corner is the receiving chamber from which the water is directly received from the pond, and contains the three sluice gates for delivering the water to the other chambers. The next, or middle chamber, contains the screens, and the bell-mouthed ends of the pipes which lead to the city. The next chamber contains the stop-gates, there being one of 30 inches diameter and one of 36 inches. On the opposite side is the waste way, which is to be used when more water comes than can well be passed at the overfall, or for purposes of emptying speedily or otherwise the pond. This is divided into two chambers, the first containing the stop-plank and the large sluice gate.



The dimensions of these gates are as follows : For waste way 5 feet by 6 feet, and the three above referred to as feeding the consumption or water delivered at Fresh Pond are each 3 feet square. The water from the waste way is discharged through an arched sluice extending about 60 feet under the dam and discharging at the base on the down stream side. Adjoining the chamber and in continuation of the dam is the overflow. This is constructed of dressed granite and has a water way of 40 feet in width. It is 5 feet thick at the crest or top, and 13 feet at the bottom, 10 feet high and rests in part upon the ledge. The level of the crest is 5 feet below the top of the dam. The overflow has been spanned by an iron latticed arched truss foot-bridge designed by the writer. This



Plan of Gate Chamber.

structure was erected by the Boston Bridge Works in a very satisfactory manner, and is a very neat and graceful structure. From the overflow the water passes between the walls of the overflow channel spaced 60 feet. These walls are made of granite from 6 to 10 feet thick, coped with dressed granite coping, the space between the walls being paved with heavy stone paving. The wall is continued around and extends up Summer street about 300 feet forming a retaining wall to hold the embankment and prevent the water, when the pond is full, from overflowing Summer street. On the top of the gate chamber previously described, has been erected a gate house of brick with New Brunswick free stone belt courses and trimmings of a light yellow shade which form a pleasing contrast with the red brick. Over the door or archway to the porch is a tablet with the inscription, "Cambridge Water-Works, 1887." The interior of the house is finished with face brick, the belt courses of light stone coming through and show-

ing on the inside. The roof is carried by two trusses made of hard pine, and the roof covering is also of hard pine boards matched and beaded and forming the interior finish, the whole finished with oil and shellac. This gate house contains all the hoisting gear for the six gates in the chamber below as well as for the stop plank, screens, etc. From the gate chamber start the two pipes leading to Fresh Pond, one a 36-inch, extending about one mile to the pumping main of the Waltham Water-Works, where a branch is provided to connect with and supply them if they should desire. From here the pipe reduces to 30 inches, and continues through the Waltham Cemetery, private lands and highways, to Fresh Pond, where it passes through a small gate house on the border and thence out into the pond, terminating there in a fancy fountain or an open end as desired. The other pipe extends only across the dam where it unites with the 36-inch. On the first mile of this line, which passes through private lands, a way was graded requiring in some places cuttings of 25 to 28 feet in depth, and fillings of 15 to 25 feet. At intervals of about one mile gates were placed, and the whole line has been fitted with air valves on the summits, and blow offs on all the low points. The whole distance to Fresh Pond is about eight miles, and with the arrangements provided repairs can be made if necessary without emptying more than one mile of the pipe. The basin which has been prepared in connection with this dam extends about one and a quarter miles up the stream, is about one-quarter mile wide, with bold and rocky shores. The available depth of water when full is 20 feet, and it will contain about 354,000,000 gallons. The bottom and sides have been carefully grubbed and cleaned by removing the mud from the bottom (of which about 80,000 yards were taken out) or covering with gravel, removing the trees, stumps and other objectionable matter. While this basin is quite small it is a very good one, there being practically no shallow water. The possibilities of a further development of the stream are also good. Four miles further up the stream is Beaver Pond, where a basin can be built with a depth of water of about 15 feet and a storage capacity of about 680,000,000 gallons, and on another branch the Hobbs Brook, a basin can be built of an equal capacity, though it is not expected that these or either of them will be needed for many years. It was thought best to secure the possible sites for dams to create these two basins, and this has been done. For supplying Roberts' mill with water during the construction of the works a No. 9 Blake steam pump was set up near the mill, a suction laid to Charles River, the mill piped and water to the amount of about 300,000 gallons daily have been pumped at the expense of the city of Cambridge.

The work of blasting the ledges and cleaning the trees was performed under a contract with Messrs. Scully & Gill; the work of constructing the dam and basin by Messrs. Henry H. Pike & Son; the gate house by Marshall N. Stearns; the gates and valves by the Coffin Valve Company; the pipe and special castings by Messrs. R. D. Wood & Co.; grading the pipe line, Thos. F. & J. J. Maney; while the larger portion of the pipe laying and work at Fresh Pond has been done under the charge of Hiram Nevons, Superintendent of the Cambridge Water-Works. In the plan-



STONY BROOK DAM—CRAM'S STEAM PILE HAMMER,

ning and construction of so large and important a scheme of works many questions have arisen, and the services of our consulting engineer, Mr. N. Henry Crafts, have proved of great value, as well as those of Mr. Lewis M. Hastings, who designed most of the structures, and Mr. Geo. Davis, who acted as resident engineer in charge of the construction, assisted by Benj. F. Bates and many others who have been employed on the works.

DISCUSSION BY JOHN R. FREEMAN.

Percolation Through Embankments.

There came up in my practice last October a case which will, I think, be of interest to all of us who have just listened to the very interesting and instructive paper of Mr. Barbour, as bearing upon the question of percolation through the gravel banks of the pond adjacent to his dam, and is instructive for comparison with the two carefully and elaborately constructed embankments that have just been described to us, as illustrating the stability of one hydraulic embankment which was "reduced to its lowest terms."

I refer to the embankment of the Nashua Manufacturing Company's canal, which conducts some 600 cubic feet of water per second from the Nashua River down through the woods a distance of about two and a quarter miles, and delivers it to the water wheels of the mills, where it develops some fifteen hundred horse-power.

This canal was first built about sixty years ago, in days before hydraulic engineers had much to do with such matters, and instead of following a straight line across the broad and sandy plain, as would be done to-day, its builders added fifty per cent. to its length, and followed the upper edge of a moderately steep sand and gravel bluff which marks the outline of a terrace lying back 500 feet or so from the river, digging into the top corner of the bluff and depositing the excavated material on the side toward the river, thus forming the bank. Thus for a distance of a mile and a half the canal and the embankment are of the general form shown in the upper sketch.

Instead of a depth of 4 to 5 feet above the water line, such as we usually consider necessary in this latitude for preventing injurious action of frost, there are here long stretches where the height of the embankment is but a little more than two feet above the water; though it may be stated that at first the water in the canal was not carried so high by about two feet as in later years. The thickness of the bank is moderate, and instead of being composed wholly or in part of impervious material, it is composed wholly of material which would serve well for making a filter.

There is not a trace of clay in its composition; indeed no clay is found within a dozen miles from there. The natural ground underlying the canal contains in some places layers six inches to a foot thick of gravel coarse as hen's eggs mixed with peas. The embankment was built of gravel and sand—the finest and closest of which would make good mortar sand—and the builders put in no sheet piling, puddle wall, or priming of any kind.

Yet this embankment thus built has kept tight and done good service summer and winter, for sixty years; and, with three exceptions, there have never been breaks or dangerous leaks.

The Nashua River has its course largely among meadows, and in a country which, though hilly, is not mountainous; and its power is so thoroughly utilized throughout its course that many mill ponds exist which, as a whole, make the course of the water rather sluggish, and thus the mud carried in suspension, or the amount of silt deposited down here at Nashua, even at times of freshet, is small—very small in comparison with that in the neighboring Merrimack.

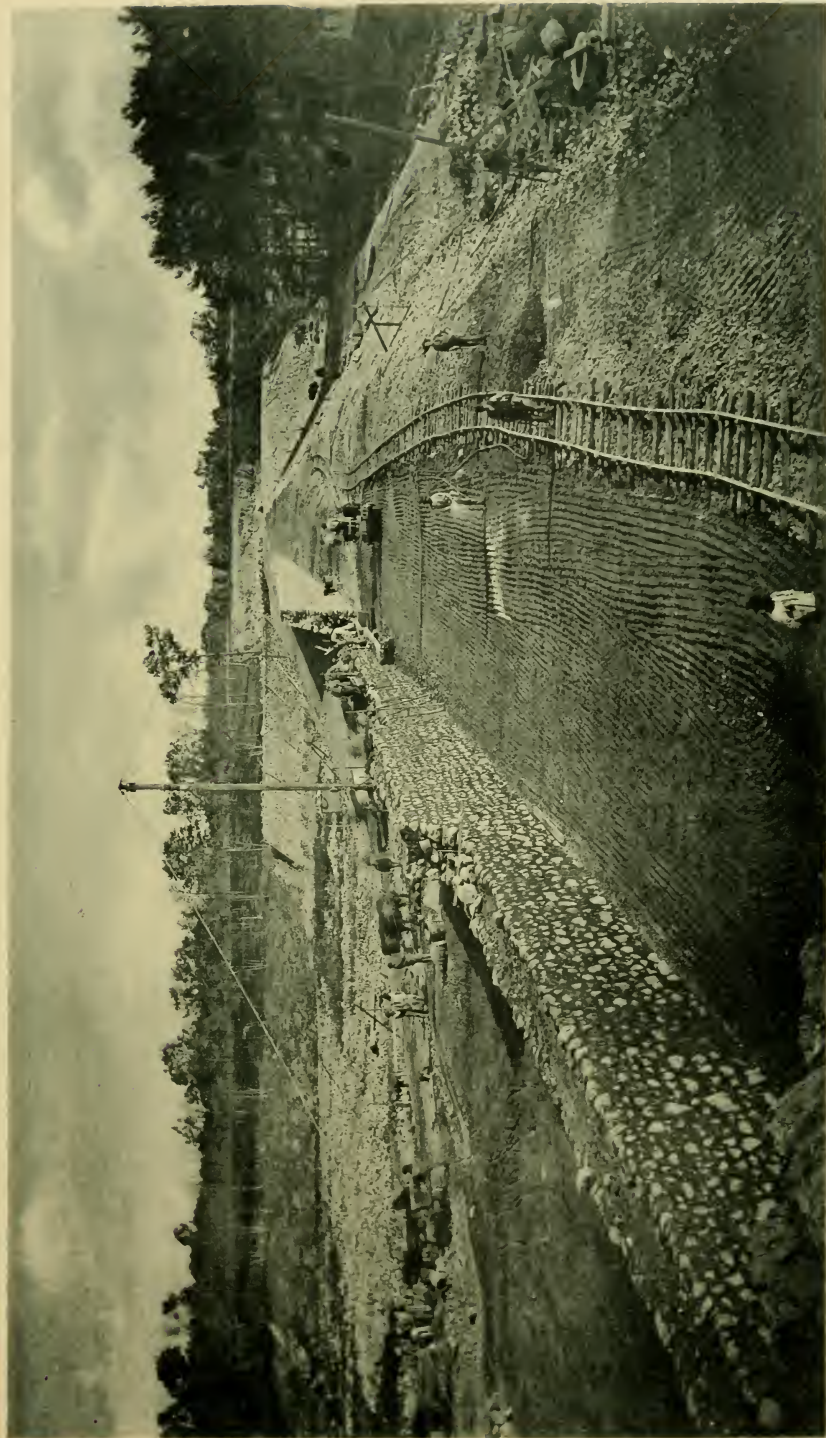
Yet we know that samples from natural river waters which in their bed appear very clear are made vastly more clear by careful filtration; and makers of fine writing paper know how few weeks or days it takes a good sand filter to become clogged when supplied with even ordinarily clear river water.

The secret of the permanence and tightness of this embankment, if indeed so plainly apparent a fact may be termed a secret, is that the whole wetted interior surface of this canal has become coated with a somewhat slimy deposit, and the sand and gravel of its bed impregnated and filled to a depth of from one to several inches with this somewhat slimy, muddy, silt-like deposit which practically prevents percolation to any noticeable extent: and with regard to the fact that although the top of the embankment is in places but two feet above the water line it has not suffered more from frost, I think we may consider the reason evident in the fact that since this thin coating of clogged sand stops the filtration of water, all that portion of embankment lying outside it is as free from standing water as the ballast of a railroad embankment, and therefore no more liable to upheaval from frost.

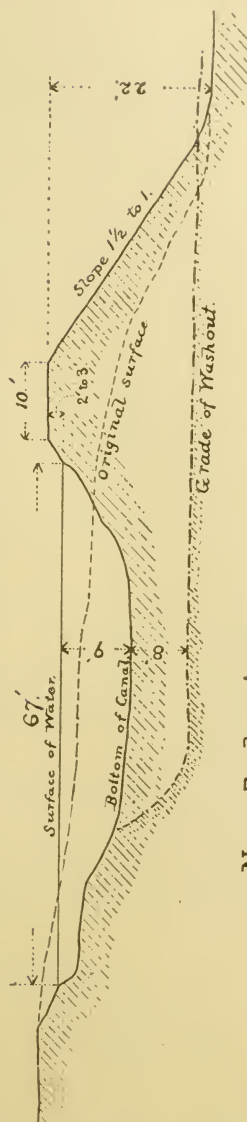
I intimated a moment ago that there had been three breaks in this embankment. The first two of these occurred thirty years and more ago, and it is not now possible to learn their cause with certainty. The third break occurred in October last, and it was in superintending the repairs on this that my intimate acquaintance with this structure came about. Hastily summoned to Nashua, I found that 150 feet of the embankment was totally washed away and the bottom gouged out to 9 feet below the bed of canal, and that for a further distance of 500 feet the inner half of the embankment had been cut away by the swift current of the escaping water, and that the bed of the canal was more or less gullied out for a total distance of 1,250 feet.

There was no eye witness to this catastrophe, as it occurred in the woods a mile or more away from either the mills or the head gates. The sudden lowering of the water was noticed at the mill, and the gate-keeper notified by telephone, "Something has happened somewhere; shut down quick!" By the time men arrived the canal was empty, and the break completed.

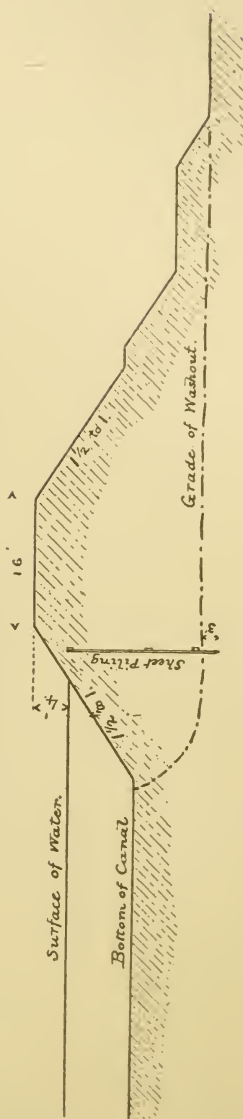
A careful study of the surroundings, the earth at edges of break and the débris, and a very careful examination of the scars on bushes and trees in front of the break, made me confident that the hole progressed rapidly from small beginnings, and that in all probability the cause of the break was not the loose porous character or the small thickness of the embankment, but that the cause was a muskrat. This was a spot where muskrats abounded, and even in the remaining bank close by the break a rat hole was found extending half way through.



Original Embankment, Nashua Canal.



New Embankment



Concerning the repairs, I will take time to mention only what bears on the matter under discussion, viz., the percolation through gravel.

During the three weeks taken to complete the repairs the gates at head of canal were not tightly closed, and thus a stream of water about 10 feet wide by 6 inches deep continued flowing down bed of canal with a velocity of about two feet a second, and without noticeable diminution of its volume until it reached the point near the break where the erosion and gulling of bed of canal began. Then in going a distance of about a hundred feet all this large quantity of water sank from sight in the porous gravel and completely disappeared.

This shows the leaky nature of the ground with which we had to deal. Probably just below the surface there was one of those strata of gravel coarse as eggs mixed with peas to which I referred in the beginning. Several hundred feet away, out half way to the river bank, I found a stream of clear water quietly oozing up, which I took to be the same as that which was disappearing in the canal.

The mill with its fourteen hundred operatives was idle, while interest and taxes were going on. Its goods were sold ahead and the selling house crying for their delivery; and the first instruction that I got from the agent or manager of the mill was the admonition to bear in mind that each day's complete idleness of the mill meant a loss of \$500. Thus we had to work lively; and though all things were not done just as I would have preferred, we found our main warrant for the course pursued in that we knew we were building a much better embankment than the one that had stood for so many years.

A section of this new embankment built is shown in the lower sketch. The material was wheeled over from the in-shore bank. It was almost entirely of material which would have made excellent coarse mortar sand, and was deposited in layers about one foot thick, leveled off and thoroughly wet down by streams from 2-inch hose and a large steam pump; and that part of the bank lying within 3 or 4 feet each side of the piling was thoroughly rammed as deposited.

A line 700 feet long of 3-inch northern pine sheet piling was placed as shown in the sketch. The bottom of this was driven only 3 feet below the surface left by the washout. Not a particle of clay went into the embankment, for none could be procured unless hauled by carts from the railroad some little distance through the woods. I realized fully in building this embankment that what we had constructed was so far really *only a gigantic filter!*

The first question therefore was, how to clog this filter, and as I was called away from Nashua by other work I left orders that mud or muck which had in course of years been deposited to a depth of several inches in a large pool on the in-shore side of the canal, and also along the in-shore bank of the canal itself, be scattered and deposited in bottom of canal at the place referred to above, where the stream running down along canal sank into the gravel and disappeared from sight, and that then water be let in very gradually, raising its height only about a foot each day, and that meanwhile men with shovels be strung along the in-shore bank of canal upstream from the break who should scrape up the deposit of mud and silt from the in-shore part of canal bed

and throw and scatter it in the water, thus keeping the water turbid as possible, meanwhile maintaining a very sluggish current through the canal.

Considering their anxiety to get the mill started, it is not strange that in the absence of the engineer an abridgment of this process was tried, and since the embankment looked good and strong the canal filled at once half or two-thirds full.

In the course of a few hours water filtered through the embankment in such quantities as to frighten them, and the canal was emptied quickly as possible. From what I could learn on my return, I got the impression that the amount filtering through the new embankment, oozing from its outer face, and showing itself in a stream flowing at foot of slope, was about equivalent to a stream three feet wide by eight inches deep, with a velocity of three feet per second; while, of course, some considerable quantity passed away under ground and was not visible.

After drawing off the canal again, a layer composed of a mixture of loam and muck and mud was puddled in on bottom of canal, and then when filled the second time it was filled gradually and the water kept as turbid as possible while filling, as previously urged.

A considerable quantity of water still filtered through, though very much less than before, but ran clear and grew less day by day, and even a fortnight after filling I found the visible percolation flowing along outside of new bank amounted to a stream 2 feet wide by 2 inches deep, flowing about 3 feet per second, and down along the old and uninjured bank there was still half a dozen places where water came out almost like a boiling spring, say 20 to 40 gallons per minute. At each of these there was a little cone of fresh, clean sand containing 1 to 5 cubic feet, and I confess they looked rather startling; but the water then flowed perfectly clear and these "springs" diminished day by day.

These leaks in old embankment were undoubtedly induced by the washing off of the coating of slime and mud from bed of canal in spots by the rapid current toward break at time of washout, and perhaps was aided by the cracking of this coating when dried by the sun during the time the canal was empty.

All these leaks in the old bank and all the visible filtration from the new bank ceased entirely in the course of two months or so, and I am told that to-day the canal is tight as one could wish.

In the above work I was guided and encouraged by things I had seen during my engineering experience with the Essex Water Power Company, at Lawrence. Mr. Mills desired to deepen the main canal slightly in places, and the cheapest way to do this was to plow up the bed and then let the current wash the loosened sand out through the drain gate.

Each time this was done there would, soon as the canal was filled, be trouble from water filtering into the basement of an adjacent mill which stood considerably below the water level in the canal, and uneasiness in the minds of some persons was thereby caused; but it was found this leak would gradually cease, and the whole thing was repeated so many times as to leave little doubt but that the leak was due to breaking the

skin on the bottom of the canal, and the stoppage of the leak due to clogging the fresh surface by the silt carried by the river in suspension ; but the Merrimack carried much more silt than the Nashua river.

I have mentioned all this for its bearing on the question which some one has raised regarding the percolation or leakage through the gravel banks of Mr. Barbour's reservoir, and the implication that perhaps these leaks might be a source of danger.

In view of the facts I have stated, may we not feel confidence that these banks of the Stony Brook Reservoir will continually grow tighter? I have myself never seen Stony Brook or its embankment, but though it might be thought that Stony Brook was too clear to clog a filter like this, does not Mr. Barbour's statement of the quantity of mud which he dug out from its bed at the site of the reservoir show that there is some such matter in suspension, and that results similar to those at Nashua may be expected?

LAWRENCE DAM ACROSS MERRIMACK RIVER.

BY RICHARD A. HALE, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

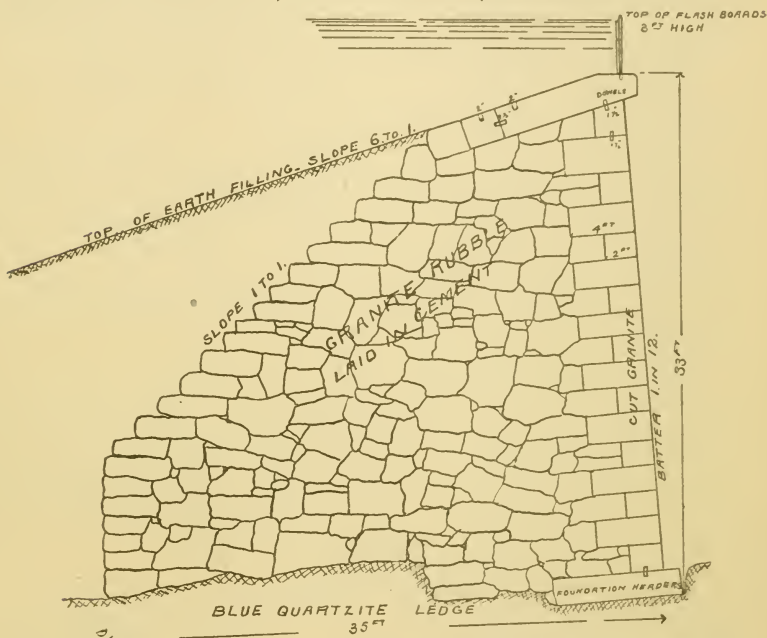
[Read June 20, 1888.]

The Essex Company's dam across the Merrimack River at Lawrence was commenced in July, 1845, when excavation was begun. The first stone was laid September 19, 1845, and the last stone September 19, 1848, three years being taken for its construction. It is a substantial structure of stone masonry, running obliquely across the river, and has a total length of 1,629 feet, including the wing walls. The length of the north wing wall is 405 feet, and the south wing wall is 324 feet, these walls extending to meet the walls and guard locks of the canal. The overfall is built on a curve, and the length of overfall is 900 feet, with the middle ordinate 14.98 feet. A section of the overfall is shown in the accompanying sketch. It is about 35 feet broad at the base, and $12\frac{1}{2}$ feet at the lower end of the coping crest stone. It has an average height of 32 feet, and a maximum height of $40\frac{1}{2}$ feet. The front face has a batter of 1 in 12. The cap stone is level for about 3 feet, and then slopes 1 foot in 3 feet for 12 feet beyond. The back is then stepped off at an angle of 45 degrees. The face of the dam is all dressed stone, and the remainder of the dam is solid rubble work.

The foundation was prepared by blasting out a trench in the rock, and cutting away all loose material till solid rock was reached, thus forming a series of steps. The first course of the foundation is composed entirely of headers, and the next course all stretchers doweled to the foundation course. The headers and stretchers of each course are dovetailed together, and the capping stones are doweled to each other and the next course below. The dowels at the top are set in brimstone, and in other portions of the dam are set in the ordinary cement used about the dam. On the front side the structure is carried up with split granite stone, hammered bed and build, the vertical joints being $\frac{3}{8}$ inch, and laid in course 16 inches to 24 inches rise. The remainder of the masonry was of rough stone, laid as compactly as it was possible to lay them without hammering, well bonded together, and to the front courses by stones of

large dimensions. The walls on either side of the overfall are carried up 10 feet higher than the crest, and extend around to meet the walls of the canal.

In the construction, coffer-dams were built inclosing certain portions of the river, and the walls brought up to certain heights, the water in the meantime being allowed to flow over other parts of the dam. New coffer-dams were then built inclosing those portions not built, and the water was permitted to flow over the parts completed, which were left with a smooth, even surface and covered with rough sheathing of plank. The deepest portion of the river was first inclosed and brought up to the level of the rest of the bed, and then carried up as described.



Section of Lawrence Dam.

A portion near the principal arch of the bridge below the dam was left low to allow the passage of rafts and logs till near completion, when navigation was closed for five months. The following is taken from specifications which were closely followed in building the dam.

The lower front course is to be entirely of headers, not less than 18 inches deep and not less than 8 feet long, let into the rock or bolted to it in such a way as to prevent sliding. They are to project one foot from face of wall, and are to be laid in level stretches lengthwise of dam as long as the uneven surface of rock will permit; that is to say, 30, 40 or 50 feet or more running lengthwise of the dam to be laid at the same level, then a step made and another level carried on. The front face is carried up with split stone laid in courses, three-eighth inch joint, ham-

mered to a fair bed 2 feet back from the face. Joints are at right angles to face, which has a batter of one inch to the foot. Headers are to run back 4 feet from the face, and to be laid as often as once in 8 foot lengths of course, breaking joints one above the other.

The crest of the dam is to consist entirely of headers not less than 2 feet deep and 9 feet long, hammered to three-eighth inch joints, and projecting 1 foot beyond the face of dam. These headers to slope backward 1 foot in 3, and every stone to be bolted to the stone underneath its lower end by an iron bolt $1\frac{1}{2}$ inches diameter, set in brimstone or cement, according to location.

The stone in the rear of the headers on the crest to be laid as stretchers, and not to be less than 5 feet long, and the headers to be secured to these by iron clamps. Ends of the land wall, where they join the crest, are built of heavy splint granite stone similar to the face of dam.

In the main body concrete may be used instead of mortar to fill the spaces, the stones being smeared with cement.

In the capstones of the dam are drilled two rows of holes 6 inches deep and sufficient diameter in which to insert iron pins $3\frac{1}{2}$ feet long and $1\frac{1}{2}$ inches diameter, to support flash boards by which the water can be raised 3 feet above the crest of dam—the down-stream row of holes is 18 inches back from the face of the dam and spaced 20 inches centre to centre supporting flash boards 16 feet in length. In freshets, when the water rises to a height of about Ref. 42, or 8 feet deep on the crest of the dam, the pressure bends the pins and carries away the boards, thus preventing damage from flowage.

When the water falls in the river the flash boards are renewed and the second row of holes is used for inserting a row of pins, against which flash boards are placed to shut off the water and to allow the scow, used to replace the flash boards, to rest against them while bent pins are taken out and replaced by new ones. The scow is 50 feet long, and is pushed along the line as the boards are renewed all of the way across, or until the water is brought up to a sufficient height.

The total cost of the dam was \$250,000.

Material used in construction was as follows :

Rock excavation.....	1,700 cubic yards.
Masonry in cement.....	29,000
Surface of hammered granite.....	148,000 square feet.

The contract prices paid at this time were as follows :

Masonry of split granite laid in courses in cement, per cubic foot.....	\$0.20
For hammering the split stone, bed and build, per superficial foot.....	.08
Masonry of rough stone, from Andover ledges, laid in cement or concrete, per cubic yard.....	2.00

The above prices include all materials, except cement, which is furnished by the company.

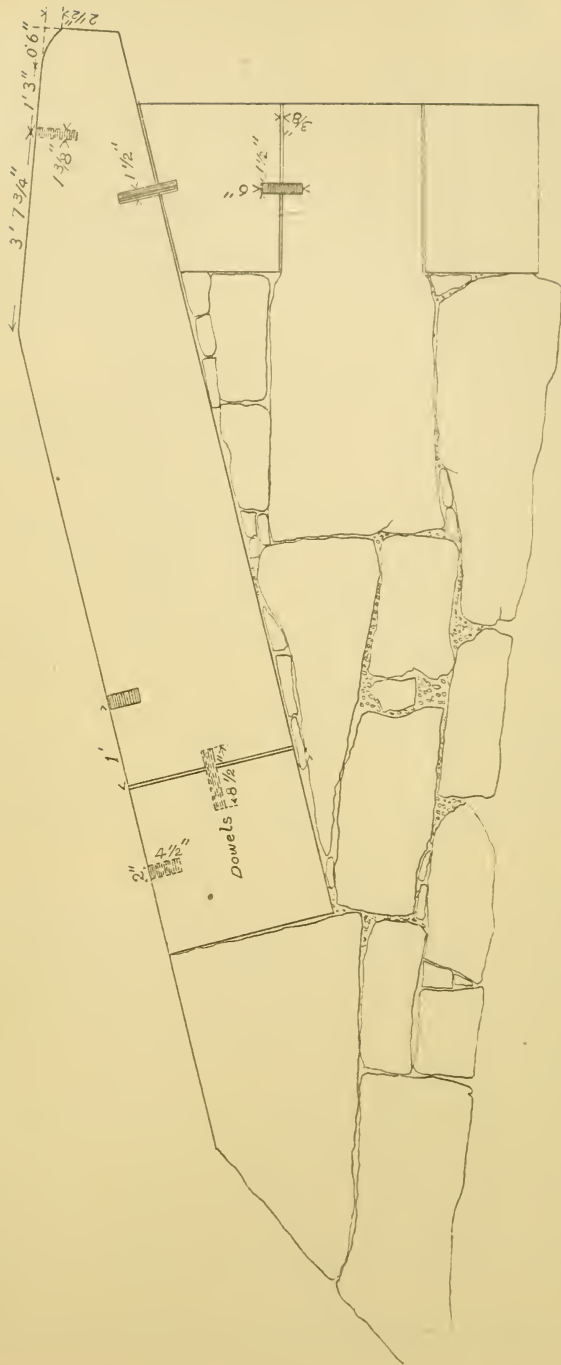
For rubble masonry, laid dry, per cubic yard.....	\$1.75
For excavations in the bed of the river, not solid rock, per cubic yard.....	.25
For excavation on land, wing walls, etc.....	.15
For excavation of solid rock, per cubic yard.....	1.00

The wages of laborers varied from \$0.84 to \$1 per day. Stonecutters, masons and carpenters, \$1.50 to \$1.75 per day.

The cement used was principally Lawrence's Rosendale cement from Rondout, N. Y.

The proportions of sand and cement were as follows:

Cement mortar: $4\frac{1}{2}$ cubic feet of cement, 6 cubic feet sand.



Section of Top of Dam.

Lime and cement mortar: 5 cubic feet of cement, 2 cubic feet lime paste, $10\frac{1}{2}$ cubic feet sand.

Cement beton: $4\frac{1}{2}$ cubic feet of cement, $4\frac{1}{2}$ cubic feet of sand, 9 to 12 cubic feet broken stone.

Lime and cement beton: 17 cubic feet of cement, 8 cubic feet lime paste, 48 cubic feet sand, 126 cubic feet broken stone.

A mortar of the consistency of thin cream, composed of cement and water, was used to brush over the surface of the stones where beton was to be laid, to ensure cohesion between the beton and stone work of dam.

Cement mortar was used in setting foundation headers for distance of 8 feet back from the face of the dam, in the rear of the dam for 5 feet back, also on top of the dam and in wet places in dam.

Lime and cement mortar was used in other places.

Cement beton was used behind the granite face of the dam and in wet places in the body of the dam to fill up spaces between rubble masonry.

At the present time there is no indication of any crumbling of the cement about the joints or any change in the structure.

The chief engineer who designed and laid out the structure, including the canal's head gates, etc., was Charles S. Storow, Esq., of Boston. He was also agent and treasurer of the Essex Company, which position he filled till a few years since, when he resigned, taking a less active part in some respects, but continuing his connection as President and director of the company, which position he now holds. Capt. C. H. Bigelow was the assistant in charge, who had the advantage of considerable experience in masonry previous to his service here.

Too much cannot be said of the skill and boldness of the enterprise at this time when so few similar stone structures were in existence, and the permanency of the work, together with the admirable system of canals, head gates, mill sites, etc., and the general laying out of the city constitute a lasting monument to Mr. Storow and his associates.

DISCUSSION BY J. R. FREEMAN.

If the hour was not so late, I would like to add a few words to what Mr. Hale has said, and grow enthusiastic meanwhile, for this dam has now stood the frosts and freshets of more than forty years without leaking a drop, starting a stone or opening a crack a hairs-breadth, or costing its owners a single dollar for repairs or protection. It was the precursor of the stone dams at Lowell, Manchester and Lewiston, was completed before the timber dam at Holyoke.

It was built in a day when there were few precedents to guide the engineer in designing such a structure, and it stands to-day, so far as I know or can learn, the most magnificent milldam in the world.

Though built forty years ago the details of carrying out the work, the character of the supervision for securing the best of work form a good guide for the engineer of to-day. Every barrel of the cement was tested, and though, of course, our present improved appliances for such test were not then known, yet the tests made sure of its hydraulic properties.

To Capt. Bigelow, whose training in the engineer corps of the U. S. Army at fortification building had made one of the most thorough



Plan of the Method of Arranging the Common Headers and Stretchers.

masons of his day and generation, much of this excellence was due ; but I can hardly let the occasion pass without a word about its designer and chief engineer, who was one of the charter members of this Society of ours, and whose engineering experience now covers a period of nearly sixty years.

Charles S. Storrow graduated from Harvard in the famous class of 1829, with the poet Holmes, the eminent divine James Freeman Clarke, and the mathematician and astronomer Pierce. With a clear and definite purpose he chose the profession of civil engineering at a time when engineering was in this country yet an almost unknown profession. He went abroad and studied several years in the best schools of France, and when fairly entered on the practice of this profession a half century ago he stood equipped, I doubt not, as the best educated engineer in America.

His designs were all studied in the clear light of science, and as a result have stood the test of time. The water power whose development he superintended stands alone among our great water powers as one where the end and magnitude were clearly seen and correctly estimated in the beginning and continually kept in view, and the details of the design in areas of sluices and sizes of canals all carefully adjusted thereto.

A large share of his attention was so soon diverted from his chosen profession by large financial and business responsibilities, and he seeks to appear so little in the public eye, that though there are those among us to whom his acquaintance and friendship have been for years a continual inspiration, there may be some others among us who hardly realize that he still walks the streets of Boston, a fine example of

“ How far the gulf stream of one's youth may flow
Within the Arctic circle of his life.”

A BRIEF DESCRIPTION OF THE QUINCY DAM.

BY LUCIAN A. TAYLOR, MEMBER OF THE BOSTON SOCIETY OF CIVIL
ENGINEERS.

[Read June 20, 1888.]

The dam being built by the Quincy Water Company is situated on Town Brook, in Braintree, Mass., one and one-fourth miles above the pumping station and wells of the company on the same stream. The water-shed of 1,000 acres is very largely covered with a growth of hard wood and brush, extending to granite hills, several hundred feet in height above the valley. There is very little tillage land, and it is very sparsely settled. The reservoir, which will cover about 50 acres, is situated on two brooks, and is in the general form of a Y, the dam being about 600 feet down stream from the junction of the two brooks. The general slope of the valley is about one in one hundred, with side slopes generally very steep, from ten to thirty in a hundred. The general direction of the valley is from east to west. The divide on the north side for one-half mile from the dam is a low sand and gravel plain, against which the northerly end of the dam abuts, the level of each being practically the same, and the slope of the plain being about the same as the valley.

The length of the dam (which runs nearly north and south) will be

about 550 feet, and its height 36 feet above the bed of the brook. The width on top will be 20 feet, with outer and inner slopes, two horizontal to one vertical. The inner slope will be covered with a pavement about 2 feet in thickness, and the outer slope and top covered with a layer of loam and seeded.

The embankment is composed mainly of gravel placed in 6-inch layers, watered and rolled with a heavy grooved roller.

About 100 feet of the northerly end of the dam abuts on the steep sand and gravel hill. About 150 feet southerly, in the lower part of the valley, is gravel and sand to a depth of from 15 to 30 feet. The entire southerly slope is a compact clayey material with many large surface boulders. Under the entire base of the embankment the natural soil was excavated to a depth of at least 2 feet, and in the valley to a depth of from 4 to 6 feet. The embankment at the northerly end is stepped into the hill to a depth of from 8 to 10 feet, and commencing 150 feet from the northerly end of the dam widens by a curve to 110 feet on top, where it connects with the original hill.

Across the centre of the valley for a distance of 193 feet along the centre line of the dam there were driven two rows of hard pine grooved and splined sheet piling 7 feet apart, one row of 6-inch on the upper side, and a row of 4 inch down stream. This piling was driven through the sand to a bed of compact gravel and boulders and into the gravel hill to a depth of 35 feet below the surface. The material between the sheet-piling was excavated to a depth of from 15 to 20 feet below the surface to a foundation of compact gravel and almost entirely free from water. This trench was filled with concrete in 6-inch layers. A masonry core wall 7 feet in thickness was built on this foundation and will extend 2 feet above the level of the rollway and $2\frac{1}{2}$ feet thick at the top. The row of 6-inch sheet piling was extended 117 feet, making an angle up stream of $34^{\circ} 15'$ and extending beyond the end of the dam 80 feet. A trench 12 or 13 feet deep was excavated and the piling driven 25 feet below the bottom of the trench to hard foundation. The upper 3 feet of the piling was enveloped in concrete, which extended to the same height as the wall in the main embankment.

Near the foot of the southerly slope and south of the sheet piling are 2 lines of 20 inch cast iron pipe extending through the base of the embankment enveloped their entire length in a masonry wall embedded in a firm clayey foundation extending to a gate house 60 feet up stream from the top line of the inner slope. There is also a line of 6-inch pipe laid between the 20-inch pipes to act as a drain in case of clearing the gate chamber. One line of 20-inch pipe terminates in the centre of the gate house and one line passes through the upper wall and draws from the bottom of the reservoir. All the pipes have valves in the centre of the gate house.

The gate house foundation is 10 feet in depth and 21 feet square. At the level of the pipes the gate house is 20 feet square and 14 feet at the top of the dam, with gate chamber 8 feet square the entire depth.

The upper or reservoir side has an opening $2\frac{1}{2}$ feet wide, extending from a point 8 feet above the bottom of the pipes to a level of the top of the dam. This opening is arranged with iron guides, with composition

faces set in brickwork for the reception of screens and stop plank, so arranged as to draw from the surface of the reservoir or any other elevation. This is to be surmounted by a brick building with granite trimmings. A line of 12-inch pipe will be extended to the pumping station during the present season. The rollway is at the southerly end of the dam and is 25 feet in width, and the overfall stone 5 feet below top of the dam.

The side walls and bottom will be laid in cement masonry and extend to the bed of the brook below the dam.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 21, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad station, Boston, at 19:30 o'clock, President FitzGerald in the chair, eighty-two Members and thirty-two visitors present.

The record of the last meeting was read and approved.

Messrs. Frank A. McInnes, J. Parker Snow, and J. Frank Williams were elected Members of the Society.

The following were proposed for membership:

Henry F. Bryant, of Brookline, Mass., recommended by A. H. French and G. F. Swain; Levi G. Hawkes, of Saugus, Mass., recommended by D. W. Pratt and H. C. Keith; and George A. King, of Taunton, Mass., recommended by Phinebas Ball and W. R. Billings.

On motion of Mr. Howe, the Secretary was requested to tender to Mr. James T. Furber, General Manager, Boston & Maine Railroad, the thanks of the Society for courtesies received on the occasion of the visit to Newburyport.

Mr. F. O. Whitney, for Committee to prepare a Memoir of Henry F. Walling, submitted its report, which was read and accepted.

The Secretary read a communication from Mr. James D. Mason describing the tunnel recently constructed in Milwaukee for pumping the water of the lake into the river for flushing purposes.

Mr. Alphonse Fteley gave a very interesting description of the new Croton Aqueduct, which was illustrated by lantern views.

[Adjourned].

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

NOVEMBER 7, 1888:—The 295th meeting was held at the Lindell Hotel, being a celebration of the twentieth anniversary of the formation of the Club. There were present Messrs. Bartlett, W. H. Bryan, Engler, Gale, Glasgow, Gould, Holman, Hubbard, Jewett, Laird, R. E. McMath, Thos. McMath, E. D. Meier, Melcher, Meysenburg, Robt. Moore, Mueller, Myers, Nipher, E. C. Parker, R. Parker, Penny, Pond, Russell, J. A. Seddon, Bathurst Smith, Stockett, Sypher, Thacher, Wheeler, Zeller. At 8:45 the members present sat down to supper. After doing justice to the repast, the President called on the Secretary, who read the programme for the coming year, as prepared by the Executive Committee, as follows:

November 7—Supper in honor of Twentieth Anniversary.

November 21—"Smoke Prevention," Robert Moore, C. E.

December 5—Annual meeting. Reports of Officers and Committees. "Condensers for Steam Engines," Prof. J. H. Kinealy, A. and M. College of Texas.

December 19—Address of retiring President, M. L. Holman, Water Commissioner, city of St. Louis. "Changing the Gauge of the Ohio & Mississippi Railway," Isaac A. Smith. Manager St. Louis Transfer Railway.

January 2, 1889—"The Interlocking System of the St. Louis Bridge and Tunnel Railroad," N. W. Eayrs, C. E., St. Louis Bridge Company. "A New Power Drill for Quarries and Mines, with Notes on Mining in Colorado," J. A. Ockerson, Manager Silver Age M. & M. Company.

January 16—"Wrought Iron and Steel Eyebars," Carl Gayler, Bridge Engineer, City. "A Burr Truss," Prof. A. E. Phillips, Purdue University.

February 6—"Rainfall and River Discharge in the Mississippi Valley," Prof. F. E. Nipher, Washington University. "Adding Machines," N. W. Perkins, Jr., M. E.

February 20—"Elevated Railroads," Geo. H. Pegram, consulting engineer. "Tests of, and Specifications for, Cast Iron," Prof. J. B. Johnson, Washington University.

March 6—"Shortage on Coal in Car Lots," Thos. D. Miller, manager Fort Worth (Tex.) Gas Company. "Improving the Channel of the Mississippi," Winslow Allderdice, consulting engineer.

March 20—"Street Car Running Gear," B. F. Crow, superintendent Brownell & Wight Car Company. "Some Reminiscences in connection with the Construction of the Union Pacific Railroad," C. H. Sharman, superintendent Illinois & St. Louis Railroad.

April 3—"The Boiler for Use in Coal Mines," Lewis Stockett, chief engineer Consolidated Coal Company. "Steam Plants for Electrical Service," Wm. H. Bryan, M. E.

April 17—"The Sanitary Condition of the Water Supply of New York City," Prof. Charles C. Brown, Union College, Engineer New York State Board of Health. "Easement Curves, Missouri Pacific Railway," Willard Beahan, engineering department, Missouri Pacific Railway.

May 1—"Some New Theories and Experiments on Boiler and Factory Chimneys," Prof. H. B. Gale, Washington University. "Experiments on Settling Water," Jas. A. Seddon, St. Louis Water-Works Extension.

May 15—"The Trussing of the Fagin Building against Wind Pressure," Prof. J. B. Johnson. "Fire-proof Flooring," P. M. Bruner, contractor.

June 5—"The Olive Street Cable Line," W. Bartlett, engineer. "Compound Engines," E. E. Furney, Missouri River Commission.

The following applications for membership were announced and referred to the Executive Committee :

Grant Beebe, indorsed by W. H. Bryan and F. H. Pond.

Wm. S. Lowe, indorsed by H. P. Taussig and N. W. Eayrs.

Wm. J. McNulty, indorsed by J. A. Laird and A. W. Zeller.

R. L. Van Sant, indorsed by M. L. Holman and George Burnet.

A. T. Woods, indorsed by F. H. Pond and C. M. Woodward.

H. D. Wood, indorsed by F. H. Pond and W. H. Bryan.

After this came the toasts as follows:

"The Engineers' Club of St. Louis," responded to by T. A. Meysenburg.

"The Engineering Profession," responded to by Robt. Moore.

"City of St. Louis," responded to by E. D. Meier.

"The Engineer of the Past," responded to by E. C. Jewett.

"The Engineer of the Future," responded to by R. E. McMath.

Prof. Engler called the Club's attention to a movement in favor of a monument to Capt. Eads, and suggested that the Club take the lead in the matter.

[Adjourned.]

W. H. BRYAN, Secretary.

NOVEMBER 21, 1888.—296TH MEETING.—Club met at Washington University. at 8:10 P. M., President Holman in the chair; thirty-one Members and two visitors present. The minutes of the 294th and 295th meetings were read and approved, The Executive Committee reported the doings of its six meetings held since the Club adjourned last spring.

On motion of Mr. Russell the recommendation of the Executive Committee that an allowance of \$100 be made the Secretary for his year's services, was approved by the Club.

The Executive Committee having approved applications for membership from

the following parties, they were balloted for and elected: Grant Beebe, draughtsman, Pond Engineering Company; Edmund Hall, assistant engineer, M. & O. R. R.; Wm. S. Love, draughtsman, Union Depot Company; Wm. J. McNulty, assistant engineer, St. L., I. M. & S. Ry.; R. L. Van Sant, assistant engineer, St. L. & S. F. R. R.; Arthur T. Woods, professor of mechanical engineering, University of Illinois.

Applications for membership were announced from Wm. F. Schaefer and Louis Simonds, both endorsed by S. B. Russell and Max G. Schinke.

Mr. R. E. McMath, of the Committee on National Public Works, reported a deficit of about \$35, and by permission circulated a subscription paper among the Members present.

Mr. Robert Moore, Chairman of the Committee on Relations with Mercantile Library, reported that a meeting room could be had in the new building, but on what terms he was not yet prepared to state.

After some announcements by the Secretary, the paper of the evening, "Smoke Prevention," was read by Robert Moore. The author's treatment of the subject was very thorough. He showed that no saving need be expected, but that experiments showed a loss of 40 per cent. in boiler capacity when making no smoke. Most smokeless fuels cost too much, as compared with ordinary coal, to come into general use. In the author's opinion, the fuel promising the best results at reasonable cost was petroleum, already coming into extensive use. The increased cost of insurance and the odor, however, were disadvantages. Good results might be secured from that class of smoke preventers which introduced air above the grates by means of steam jets, providing no injury resulted to the boilers.

In the discussion Mr. Bryan called attention to the fact that petroleum burners were being placed under boilers in this city, and that it was expected that the increased cost would be justified by other advantages. He also mentioned furnaces at the Mississippi Glass Company fed by gas producers, where very high evaporative efficiency was reported. The general opinion of the Club was that little could be expected in this direction.

Col. Meier gave some experience which accorded well with the conclusions of Mr. Moore.

Mr. Wheeler stated that claims had been made that the soot particles were not only unobjectionable, but even remedial, from a sanitary point of view.

Mr. Bartlett gave the experience of the Olive street cable line with jets of steam and air. They were successful unless the boilers were injured.

Replying to Mr. Russell, Mr. Moore stated that the comparative costs of fuel given in his paper were based on actual values.

Mr. Holman stated that serious injury to boilers had resulted from the use of steam and air jets, and he had therefore refused to allow such devices to be applied to the water-works boilers, which are internally fired. A proposition had been received looking to the use of petroleum, an evaporation of 14 pounds of water per pound of oil being promised. The increased cost of this fuel over coal would be small.

I. A. Smith stated that while in charge of public buildings at Cincinnati a smoke ordinance was passed and he had used steam and air jets. These had since been removed, and after six years no reduction of smoke in that city was apparent.

Professor Gale was of the opinion that where steam plants of sufficient magnitude were used, gas producers would be found advantageous. There was, however, a lack of reliable data on this subject.

Some further general discussion followed.

On motion of Mr. Russell, the Executive Committee were authorized to employ a stenographer to report the discussions of papers at our meetings.

[Adjourned.]

W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

NOVEMBER 14, 1888:—The 252d meeting was held, Vice-President Jno. W. Weston in the chair.

The minutes of last meeting were read and approved.

Mr. Lewis Passmore Pennypacker, proposed at last meeting, was elected a Member.

The resignations of Mr. A. M. Kinsman, Rockford, Ill., and Mr. J. T. Dodge, Duluth, Minn., were accepted.

The following financial exhibit is compiled from report of Secretary and Treasurer: Cash reported at last meeting, \$107.82; receipts since last meeting, \$35.95; bills paid, \$82.50; cash on hand, \$61.27; new bills reported, \$56.00.

The Secretary read a letter from Prof. Allan D. Conover, University of Wisconsin, stating that a comprehensive system of tests of all the cements used in this country had been undertaken, and requesting information as to makers of cements and experience of Members. After brief discussion, the Secretary was directed to communicate with Professor Conover.

Mr. Liljencrantz, from Committee on Employment, reported that the matter had not been disposed of, and it was made a special order for next meeting.

Mr. Strobel, from Committee on Bridges, made an extended progress report and the question of legislation was discussed for the views of Members. The correspondence with other societies showed a wide and active interest. The Committee would report formally with the draft of a bill at a future meeting.

As legislation of kindred interest to engineers, the Secretary presented the desirability of expanding the duties of the State Board of Health so as to require its approval of all plans for water-works and sewerage. From a conversation with one of the Members of the Board, it was inferred that if the engineers of the State would unite in pushing the matter they would have the co-operation of the Board. No action was taken upon the suggestion.

The Secretary announced farther discussion upon Mr. Wisner's paper by Mr. B. Williams and Mr. T. T. Johnston and a compilation of data by himself, and that when the matter was all received and arranged it would be forwarded for publication.

An interesting paper, entitled "The Necessity of a Definite and Determinate System of Weights and Measures," by Mr. Chas. C. Breed, was presented by the Secretary and after brief discussion ordered printed.

Mr. Weston gave an interesting account of a mammoth electric light plant now under construction in the city of London. A general discussion in regard to the application of any motor to direct propulsion on street railways then ensued. There was some doubt of securing adequate adhesion under all the conditions of track obtaining in crowded cities.

A Committee was then appointed to present at the next regular meeting a program for the Annual Meeting, and to report upon nominations of officers and rules for their election.

Committee: Benezetette Williams, S. G. Artingstall, A. W. Wright.

[Adjourned.]

L. E. COOLEY, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

NOVEMBER 5, 1888:—A regular meeting was held at 8 P. M. in Club room, President W. B. Knight in the Chair. There were present 10 Members and 9 visitors.

Minutes of the previous meeting of the Executive Committee were read and approved.

W. H. Breithaupt read for the Committee on Highway Reform the draft of a

law prepared to be presented as a memorial to the State Legislature. Many of the local societies had given the subject favorable attention, and it was expected that a final report would be submitted in one or two months.

The Secretary read a letter from Mr. Benezette Williams, with reference to prolonging the contract with the *Railroad Gazette* for publishing the JOURNAL, and announced the following contributions to the library :

Proceedings Engineers' Society of Western Pennsylvania, Engineers' Club of Philadelphia, American Society of Civil Engineers, and a complete file of *The Mechanic*. Also, from Mr. H. J. Tullock, two handsome bridge photographs.

A paper on "Electric Railways" was read by Mr. J. F. Wynne and discussed by those present.

[Adjourned.]

KENNETH ALLEN.

NOVEMBER 19, 1888:—An adjourned meeting was held in the club-room at 8 o'clock P. M., President W. B. Knight in the chair. There were present 12 Members and 9 visitors.

The Secretary being absent, the minutes of the two previous regular meetings and those of a meeting of the Executive Committee were read by Mr. Breithaupt and approved.

Dr. Wellington Adams gave an address on "The Present Status of the Electric Railway Problem," being in part a discussion of the paper read by Mr. Wynne at the last meeting. It was discussed by Messrs. Knight, Wynne and Lawless, the latter giving a review of a recent tour of inspection of the electric railways of Allegheny, Binghamton, Richmond and Harrisburg.

KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 24, 1888:—An adjourned meeting was held at 8 P. M., at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Ry., Mr. Beckler, 2d Vice-President, in the chair. These present were Messrs. Haven, Beckler, Foss, Kelly, Wade, Wheeler, Keerl and two visitors.

Mr. F. J. Smith was unanimously elected a Member of the society.

The Committee, consisting of Messrs. Haven, Foss and Beckler, appointed at the regular meeting of 20th ult., to consider and report upon an overhead crossing of the motor line at Main street and Sixth avenue, city of Helena, submitted their report. They recommend an elevated track for the motor line along Sixth avenue, leaving the grade of the street at a point near Close street, and crossing Main and Jackson streets at elevations giving sufficient head room, thence coming to grade at a point east of Jackson street. The details of the location and construction were discussed at length—the principal point being as to whether the elevated road should be placed over the sidewalk or the centre of the street. The report was received and the Committee discharged, with a vote of thanks for the careful attention they had given to the subject.

It was moved and carried that the consideration of the final adoption of the report of the Committee upon an overhead crossing of the motor line at Main street and Sixth avenue, Helena, be deferred until the next regular meeting, and that the Secretary be instructed to inform members that the subject will then be brought up for discussion.

A communication was read from Allan D. Cowan, Professor of Civil Engineering in the University of Wisconsin, requesting information upon the brands of cement manufactured and used in this section of the country. Members are requested to notify the Secretary if they know of any brands of cement being man-

ufactured in this section of country; also, what brands they know of being used, with name and address of manufacturer.

The question of arranging a programme for the annual meeting of the Society, to be held in January, was deferred until the next regular meeting.

Meeting adjourned, to meet December 15th next, at same hour and place.

J. S. KEERL, Secretary.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional titles and many cross-references.

All readers of the JOURNAL are requested to aid in making the Index as complete as possible. All notices for this department, and all matter to be here indexed should be sent to J. B. JOHNSON, Manager Index Department, Washington University, St. Louis, Mo.

Address. *Annual, to the Engineers' Club of Philadelphia.* By T. M. Cleemann, retiring President. Gives a comparison of the growth of engineering societies and a brief review of the work Philadelphia and Pennsylvania have accomplished. *Proc. Engrs. Club, Philadelphia*, Vol. VI., pp. 225-234 (Feb., 1888).

— *of Retiring President, Engineers' Club of St. Louis.* By Wm. B. Potter. Gives brief history of the club and discusses its work and relations with other societies. *Jour. Asso. Engin. Soc.*, Jan., 1888, pp. 22-28.

— *President's, Society of Engineers.* By Henry Robinson. Reviews engineering progress during the year. *Trans. Soc. Engrs.*, 1888, pp. 1-26.

— *President's, Illinois Society of Engineers and Surveyors.* By I. O. Baker. Points out desirable changes in engineering practice of building roads, bridges, etc. *Rep. Ill. Soc. Engrs. and Surveyors*, 1888, pp. 14-27.

— *to the Institution of Civil Engineers.* Gives the address of Geo. B. Brace on assuming the President's chair. A general review of engineering. *Engineer*, Nov. 11, 1887.

— *to the Mechanical Science Section of the British Association, Bath, 1888.* By W. H. Preece, President of the section. Reviews the developments of the practical applications of electricity. *Engineer*, Sept. 7, 1888; *T. J. and Elec. Rev.*, Sept. 7, 1888; *Jour. Soc. Arts*, Sept. 14, 1888; *Sci. Am. Supple.*, Sept. 29, 1888.

Aluminum Alloys by the Heroult Process. Describes the method of producing aluminum alloys; also gives a table showing tensile strength and elongation obtained from a series of tests made at Zurich. *Engr. News*, Sept. 8, 1888.

— *Influence upon Cast-Iron.* By W. J. Keep, Prof. C. F. Maybery and L. D. Voice, before the American Association for the Advancement of Science. A valuable paper, giving details of experiments made to determine the effects of aluminum on cast-iron. Good results were obtained by its use. *Sci. Am. Supple.*, Sept. 8, 1888.

— *Recent Development of the Cowles Process.* By R. E. Crompton, before the Bath meeting of the British Association. Gives a description of the new plant for the production of aluminum at Milton, Eng. *T. J. and Elec. Review*, Sept. 14, 1888.

Alloys, Copper-Tin. A preliminary experimental research upon the mechanical properties of small castings of the alloys of copper and tin. Transverse, tension, torsion and compression tests in detail, with 81 plates and diagrams. By R. H. Thurston, Chairman. *Report Board of Testing*, etc., 1881, Vol. I., pp. 271-451.

- Anemometers.** *Experimental Investigations and Description of the Hagemann Anemometer.* By G. A. Hagemann. Translated by G. E. Curtis from the "Annuaire Météorologique" of the Danish Meteorological Institute, Copenhagen, 1877. *Journal of the Franklin Institute*, Sept., 1887, Vol. CXXIV., No. 741.
- Angle Prisms.** Discusses the construction and uses of angle prisms. *Eng. News*, May 12, 1888.
- Aqueduct, Croton, Method of Detecting Bad Work.** Gives a brief description of the methods employed to detect and repair the bad work on the Croton Aqueduct. *Engr. News*, Oct. 13, 1888.
- , *Croton, Tunnel Excavation.* A contractor's side of the tunnel excavation question. *Engr. News*, Oct. 20, 1888.
- , *Zempoala, Mexico.* Gives an illustrated description of Zempoala aqueduct, supplying the city of Otumba, which was built during 1553-7. *Engr. News*, July 7, 1888.
- Arch, Construction of a Skew.** By M. P. Paret. Gives a history of interesting points on the construction of a skew arch on the Cincinnati & Richmond R. R., near Red Bank, O. *Engineering News*, Oct. 20 *et seq.*, 1888.
- , *Stone, over South Street, Boston & Providence R. R.* Gives description, with plan, elevation and sections, of the stone arch of 40 feet span to replace the Bussey bridge. *R. R. Gaz.*, Dec. 30, 1887.
- Arches.** An abstract of a paper before the Engineering Section of Bristol Naturalist Society by Mr. C. Richardson, Engineer to Severn Tunnel. *Engineering*, Jan. 13, 1888. *Sci. Am. Supple.*, March 3, 1888.
- , *Arched Ribs and Voussoir.* By Mr. Martin, before a students' meeting of the Institution of Civil Engineers. Gives a mathematical discussion of arched ribs and voussoir arches. *Proc. Inst. C. E.*, Vol. XCIII., pp. 462-477.
- of long span and small rise, constructed with a joint at crown and springings of a hinge-like form, by insertion of lead plates in the middle third of these joints. Four such bridges described, erected 1885-87. Very good. *Zeitschrift für Bauwesen*, 1888, p. 235.
- , *Stone.* Discusses the problem of the stone arch as designed from the catenary curve. *Eng. News*, Nov. 19, 1887; *Mech. World*, Dec. 17, 1887.
- Asbestos.** By S. A. Rogers, before the Chemists' Assistants' Association. Reviews the history, occurrence and properties of asbestos. *Sci. Am. Supple.*, June 16, 1888.
- Axle, Standard for 60,000-lb. car.** A paper by A. Forsyth, presented to January meeting of Western Railway Club by the committee on axles as their report. It discusses dimensions and loads, factor of safety and friction. *Mast. Mechanic*, Feb., 1888.
- , *Standard for 60,000-lb. car.* By H. C. Meade, before January meeting Western Railroad Club. Gives comparison between the Johann and M. C. B. axles. *R. R. Gazette*, Feb. 10, 1888; *Mast. Mechanic*, Feb., 1888.
- Axles, Effects of Temperature on the Strength of.** By Thos. Andrews. Abstract of a paper before the Institution of Civil Engineers, giving valuable experimental research on the effect of varying temperatures on the resistance to impact of railway axles. *Engr. News*, Feb. 18, 1888.
- , *Steel Car.* A paper by John Coffin before the Philadelphia meeting of the American Society of Mechanical Engineers. Discusses the treatment of the axle after it is forged. *Trans. Amer. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 135-160; abstracted *R. R. Gazette*, Dec. 23, 1887.
- See Car Axles and Car Wheels.
- Batteries, Primary, for Illuminating Purposes.** By Perry F. Nursey, before the Society of Engineers. Treats briefly the principles of the primary battery, outlines its history and then describes in chronological order the various batteries brought out. *Trans. Soc. Engrs.*, 1888, pp. 185-223.
- Belting. Origin and Progress of Leather Belting.** With description of leath link belting. Paper read before the National Electric Light Association, Pittsburgh by Charles A. Schieren. *Electrical World*, March 3, 1888; *Electrical Engineer*, March, 1888; *Age of Steel*, March 10 and 17, 1888.
- Blowers, Experiments and Experience with.** By H. I. Snell, before the Philadelphia meeting of the American Society of Mechanical Engineers. *Trans. Amer.*

Soc. Mech. Engrs., Vol. IX. (1888), pp. 51-73; *Am. Engr.*, Nov. 23, 1887; *Mech. World*, Dec. 17, 1887.

Boiler, Efficiency of a, Using Waste Gas as Fuel. By D. S. Jacobus, before the Birmingham meeting of the American Institute of Mining Engineers. Gives the results of trials made to determine the efficiency of a water-tube boiler with waste gas from a blast furnace as fuel. *Am. Eng.*, Aug. 15, 1888; *Eng. News*, Aug. 15, 1888.

—, *Essex Vertical*. Describes a new internal arrangement adopted for small vertical boilers. *Engineer*, Dec. 9, 1888.

—, *Firmenich, Failure of a*. By C. F. White, before the Engineers' Club of St. Louis. Gives results of examinations as to the cause of explosion of a Firmenich boiler. *Jour. Assoc. Engin. Soc.*, August, 1888, Vol. VII., pp. 329-335; *R. R. Gazette*, Sept. 7, 1888.

—, *Locomotive, Belpaire Type*. Gives detailed drawings of a 56-inch straight top boiler designed for the new Mogul engines on the Chicago, Burlington & Quincy Railroad. *Master Mechanic*, March, 1888.

—, *Water Tube, Trial of a*. By R. H. Thurston. Gives very full details of a test of a Babcock-Wilcox water-tube boiler at Sibley College, Cornell University. *Sci. Am. Supple.*, April 14, 1888.

Boilers, Circulation in. See Locomotives.

—, *Deterioration of*. By J. M. Allen. A Sibley College lecture, treating of errors in boiler construction, and of the natural cause of their deterioration. Illustrated. *Sci. Am. Supple.*, June 9, 1888.

—, *Gas Fired*. Gives a description of Frederick Siemens' improvement in generating steam with gaseous fuels. *Sci. Am. Supple.*, March 31, 1888. *Am. Manufacturer*, May 11, 1888.

—, *Joints in*. See Riveted Joints.

—, *Pressure in Marine*. By Richard Sennett, before the Institution of Naval Architects. Discusses working and test pressures for marine boilers. *Engineering*, March 30, 1888.

—, See Oil Burners for.

—, *Specifications for*. By C. G. Darrach, before the Philadelphia Engineers' Club. Gives general specifications for boilers which require the bidder to state not only the price for the entire work, including boiler, setting, fixtures, etc., but also the economy and capacity he will guarantee. Discussed. *Proc. Engrs. Club*, Philadelphia, December, 1887, Vol. VI., pp. 179-206.

—, *Strains in Locomotive Boilers*. A paper read at the Nashville meeting of the American Society of Mechanical Engineers. By L. S. Randolph, Mount Savage, Md. Showing that the failure of locomotive boilers is generally due to unequal expansion and contraction of the fire-box sheets. *American Engineer*, May 16, 1888.

—, *Use of Kerosene Oil in*. A paper by L. F. Lynes before the American Society of Mechanical Engineers. Gives practical experience in using kerosene oil in steam boilers to remove and prevent scale. Advocates its use. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 247-258; *Amer. Engr.*, Nov. 30 and Dec. 7; *Power*, December, 1887; Abstract in *Eng. and Build. Rec.*, Dec. 31, 1887; *Sci. Am. Suppl.*, Feb. 11, 1888.

—, *United States Government Rules for Marine Boiler Pressures*. Pressure allowed for various thicknesses and qualities of plates, flues, etc. *Mechanics*, January, 1888.

—, *Water Tube*. Discussion on their uses and drawbacks. *Engineer*, Oct. 7 and 28, 1887.

Boiler Experiments and Fuel Economy. By J. Holliday, before the students' meeting, Institution of Civil Engineers. Gives details of experiments made to increase the efficiency and economy of a certain boiler. *Proc. Inst. C. E.*, Vol. XCII., pp. 336-352.

Brake, Eames Vacuum. Full description, with detailed drawings, of the Eames vacuum brake. *Engineer*, March 16, 1888; *Sci. Am. Supple.*, April 21, 1888.

—, *Manomatik*. Gives a description of the Manomatik lever momentum brake which is operated by power transmitted from the drawheads through buffer springs. Illustrated. *R. R. Gazette*, March 23, 1888.

—, *Suggestions of Radical Changes in Automatic Brakes*, especially for freight

trains. The main feature of improvement suggested is that the power of the brake should increase with the load in the car. By A. K. Mansfield. *The Railroad and Engineering Journal*, January, 1888.

Brake Tests, Westinghouse. Gives details of the test made at Weehawken with a train of 50 empty freight cars. *Eng. News*, Nov. 25 1887; *R. R. Gaz.*, Nov. 25, 1887; *Nat. Car and Loco. Builder* for December, 1887. Gives table of the tests at various places.

Brakes, Classification of Continuous Railroad. By A. W. Metcalfe, before the Students Institution of Civil Engineers. Gives a classification of railroad brakes based upon the general principles of action. *Proc. Inst. C. E.*, Vol. XCII., pp. 315-335.

—, *Freight Train.* Gives a paper by Mr. Lauder, and the discussion that followed it at the December meeting of the New England R. R. Club. *R. R. Gaz.*, Dec. 23, 1887, also *Mast. Mechanic*, January, 1888.

—, *Freight.* A paper by H. H. Westinghouse before the New York Railroad Club. Describes the construction, operation and maintenance of brakes. With discussion by the Club. *Mast. Mechanic*, February, 1888; *R. R. Gazette*, Jan. 27, 1888.

—, *Buffer.* A brief article explaining, with formulæ, the nature and action of buffer brakes. *Master Mechanic*, April, 1888.

Bridge, Arthur Kill. Gives a brief description, with plan and details of the draw-bridge recently constructed between Staten Island and New Jersey. Total length of draw, 496½ feet; clear water-way, 206 + 204 feet. *R. R. Gazette*, June 22, 1888.

—, *Brunswick, Eng.* Gives two-page plate showing elevation and details of a hinged-arch foot bridge, spans 79 feet, over the River Oker at Brunswick, England. *Engineering*, Aug. 17, 1888.

—, *Ben Rhydding, Eng.* Gives brief description with two-page plate of detailed drawings, of two lattice arches, with suspended roadway, over the River Wharfe near Ben Rhydding, Yorkshire. *Engineer*, May 25, 1888.

—, *Big Warrior River.* Gives a brief description of a 300-foot through span over the Big Warrior River, near Cordova, Ala., with full detailed drawings. *R. R. Gazette*, June 29, 1888; *Sci. Am. Sup.*, July 21, 1888.

—, *Brooklyn.* Gives report of the Committee on Terminal Facilities, and the adopted plans for the terminals. *Engin. News*, April 21, *et seq.*, 1888; *R. R. Gazette*, April 27, 1888; *Engin. and Build. Rec.*, April 21, 1888.

—, *Brooklyn, Enlarging the Capacity of the.* Gives the report of the Board of Experts on the plans for enlarging the capacity of the Brooklyn bridge; also the report submitted to the Board by Mr. A. M. Wellington. *Engr. News*, March 17, 1888.

—, See Foundations.

—, *Cairo.* By S. F. Balcom. Gives brief description of the Cairo bridge, and describes some of the details of construction and progress of the work. *Rept. Ill. Soc. Engrs. & Surveyors*, 1888, p. 75-84; and *Railroad Gazette*, June 1, 1888.

—, *Cantilever, Lachine.* Gives description with a two-page plate, with details of the bridge across the St. Lawrence River. *Engineering*, April 13, 1888.

—, *Cantilever, Sukkar.* By Wm. Parsey. Gives a description of staging and temporary erection of the Sukkar cantilever bridge at the bridge works. The bridge has a span of 820 feet, with a centre span of 200 feet. A two-page plate gives details of staging, etc. *Engineering*, March 2, 1888.

—, *Chenab, India.* Gives two pages of detailed drawing and abstracts from the specifications of the Chenab bridge, India state railroads. It is composed of 17 spans, of 206 feet each, of riveted triangular girder. *Engincer*, Sept. 14, 1888,

—, *Draw.* See Draw-bridge.

—, *Forth.* By F. E. Cooper, before the Iron and Steel Institute. Gives a general description of the methods employed in the erection of the various portions of the main span. Abstracts in *Engineer*, Aug. 24, 1884; *Engr. News.*, Sept. 22, 1888; *Sci. Am. Supple.*, Oct. 13, 1888.

—, *Forth, Erection of.* By A. S. Biggart. A paper before the British Association, treating of the problems that occurred during the erection of the Forth bridge and methods of overcoming them. Illustrated. *Engineer*, Nov. 25, 1887; *Sci. Am. Sup.*, Dec. 31, 1887.

—, *Forth, Erection of Superstructure.* By A. S. Biggart, before the Scotland In

stitution of Engineers and Shipbuilders. Describes briefly the principal features of erection of the superstructure of the Forth bridge. *R. R. Gazette*, May 18, 1888.

Bridge, Forth. Fife Cantilever Pier. A two-page plate of the Fife cantilever pier of the Forth bridge, showing all of the main tubes and connections, including junction girders completed to the full height of 362 feet, the north cantilever carried out 170 feet, the first struts and braces to a height of 240 feet, and 130 feet of the viaduct completed. *Engineer*, Feb. 3, 1888. A small view of the same in *Engineering*, Jan. 27, 1888, also *Engr. News*, March 10, 1888.

—, **Fort Madison.** By W. W. Curtis. Gives a good description of location and construction of Chicago, Sante Fe & California railroad bridge across the Mississippi River at Fort Madison, Ia., with cuts showing details of caisson and piers. *Engin. News*, June 2 and 9, 1888.

—, **Hackensack Draw.** Gives description of new draw-bridge recently built by the Erie Railroad over the Hackensack River, with drawings showing details of girders, turn-table, wedges and foundations of draw span. *R. R. Gazette*, July 20, 1888.

—, **Harlem River.** Gives plan and elevation showing the arrangement of the plan and the condition of the work just before the last segments of span No. 2 were closed. *Eng. and Build. Rec.*, Jan. 21, 1888. False works, skewback segment and hinges are shown in *Eng. News*, Feb. 4, 1888.

—, **Harlem River.** A series of articles describing the erection of the Harlem River bridge, with details of contractors' plant, staging, etc. *Engin. and Build. Rec.*, July 14 *et seq.*, 1888.

—, **Hawkesbury, New South Wales.** Illustrations and description of the method of erecting on pontoons and floating to place. *R. R. Gazette*, August 10, 1888; *Indian Engineer*, July 28, 1888; *Sci. Am. Supple.*, Aug. 11, 1888; *Engineer*, Sept. 7, 1888.

—, **Hawkesbury.** Gives illustrated description of the Hawkesbury bridge, with report of progress. Abstracted from the *Sidney Mail*, *Sci. Amer. Supple.*, Aug. 11, 1888.

—, **Highway, Overhead, N. Y. C. & H. R. R.** Gives details of the 60-ft. span overhead highway bridge erected in New York City. *R. R. Gazette*, Nov. 9, 1888.

—, **Jubilee Hooghly, River, India.** By Sir B. Leslie. A paper before the Institution of Civil Engineers, giving details of the construction of the Jubilee bridge carrying the East Indian Railroad over the Hooghly River at Hooghly. It has a central double cantilever 360 feet long by 5.2 feet high, and side spans 420 feet long and 47 feet deep. *Proc. Inst. C. E.*, Vol. XCII., pp. 73-141; abstract *Engineering*, Jan. 27, 1888; *Mech. World*, Feb. 4, 1887; *Engineer*, Feb. 10, 1888; *Engin. and Build. Rec.*, Feb. 4, 1888.

—, **Illinois and St. Louis.** By Theo. Cooper. Gives notes on the mode of setting and adjusting the skew backs on the insertion of the centre tube of the different spans, and the tests of the completed bridge. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 239-254.

—, **Kentucky and Indiana.** By Mace Moulton. A paper before the American Society of Civil Engineers, containing a full account of the construction, with extracts from specifications, tables showing tests of materials, etc., of the bridge over the Ohio River at Louisville. Plates show design, locations, strain sheet and details. *Trans. Am. Soc. C. E.*, XVII., September, 1887, pp. 111-168; abstract in *Engineering*, Jan. 27, 1887.

—, **Lifting, Tarante, Italy.** Description of a bridge at Tarante, Italy, with plates showing details. It consists of two half arcs meeting in the centre when closed; each half has a rising and rotating movement, and is worked by hand or turbines. Distance between axes of rotation, 220 feet. *Engineering*, Oct. 28, 1887, *et seq.* Brief description, illustrated. *Sci. Am. Sup.*, Jan. 14, 1888.

—, **Lifting, Utica, N. Y.** By Squire Whipple. Gives description, with elevation and cross-section, of a "lift-draw-bridge" over the Erie Canal at Utica, N. Y. *Trans. Am. Soc. C. E.*, Vol. III., pp. 190-194.

—, **Mannheim.** Gives brief illustrated description of five competitive designs for a bridge at Mannheim. *Engineer*, Dec. 16, 1887.

—, **Niagara, Replacing Towers of.** By L. L. Buck, before the American Society of Civil Engineers. Gives details of the work of replacing the stone towers of the

- Niagara suspension bridge with iron towers. *Trans. Am. Soc. C. E.*, Vol. XVII. (Oct. 1887), pp. 204-212; *Engineer*, Dec. 9, 1887; *Engineering*, Dec. 9, 1887; abstracted *Prac. Inst. C. E.*, Vol. XCIII., pp. 510-512.
- Bridge, Paderno, Italy.** Gives brief description, with elevation and cross section, of a bridge to be built over the river Adda, at Paderno, Italy. Length of main arch, 492 ft.; rise, 123 ft.; lattice truss spans, 109 ft.; total length, 997 ft. *R. R. Gazette*, Sept. 14, 1888.
- , *Petaluma Draw.* Gives brief description, with general view and plan and elevation, of the central pier of the Petaluma draw-bridge on the San Francisco & North Pacific Railroad. *Engr. News*, Oct. 13, 1888.
- , *Plate Girder.* See Girder.
- , *Pony Lattice, W. S. R. R.* Gives plan, elevation and cross-section, with dimensions of a pony lattice bridge truss built at Normanskill, N. Y., on the West Shore Railroad. Span, 86 ft.; clear width, 14 ft.; height, 10 ft., and weight, 50 tons. *R. R. Gazette*, Sept. 21, 1888.
- , *Poughkeepsie.* A series of articles on the erection of the Poughkeepsie bridge. *Engin. and Build. Rec.*, May 5, *et seq.*, 1888.
- , *Poughkeepsie.* By Thomas C. Clark. The Second Sibley College lecture describing the erection of bridge over the Hudson at Poughkeepsie. *Sci. Am. Suppl.*, May 19, 1888.
- , *Proposed North River.* By G. Lindenthal. Gives brief description of the proposed bridge, also gives a full page plate comparing the bridge with four of the greatest bridges in the world. *Engr. News*, Jan. 14, 1888, and *Engr. and Build. Rec.*, Jan. 14, 1888.
- , *North River, Proposed.* By Gustav Lindenthal, before the American Society of Civil Engineers. Gives very full details of the proposed bridge over Hudson River, at New York. Proposed dimensions are: River span, 2,850 feet; two shore spans, 1,800 feet; width, 68 feet, with six railroad tracks; height above water, 145 feet. Abstracted in *Eng. News*, Jan. 28, *et seq.*, 1888.
- , *Ravine Lowestoft.* Description, with elevation and details, of a wrought-iron arched bridge. The arch ribs are made of $\frac{1}{4}$ -inch web plate and angle iron. *Engineer*, Sept. 2, 1887.
- , *Red River, Concrete Piers.* By C. D. Purdon. Gives details of the construction of concrete piers for the St. Louis & San Francisco R. R. bridge over Red River, Texas. *Engr. News*, June 2, 1888.
- , *River Ouse, Bedford, Eng.* Gives plan, elevation and cross-section of a foot-bridge of 100 ft. span, practically without abutment. *Sci. Am. Suppl.*, Sept. 8, 1888.
- , *Staging, Sukkur, India.* A brief description, with large colored plate, of the staging for the main pillars and guys of the 820-foot cantilever span of the Sukkur bridge. *Indian Engineering*, Nov. 5, 1887.
- , *St. Louis, Reconstruction of the Floor of.* By N. W. Eayrs. Gives details, with drawings, of the plan adopted in the reconstruction of the railroad floor of the St. Louis bridge. *R. R. Gazette*, Aug. 31, 1888.
- , *Suspension, Vishwamitri River.* Short description and abstract from specifications of a chain suspension bridge of 190 feet span, with two large plates showing elevation and details. *Indian Engineering*, Dec. 10, 1887.
- , *Sin Ho, China.* Brief description, with elevations, cross section and half plans showing bracing of the Sin Ho bridge. *Engineer*, Dec. 9, 1887.
- , *Three-Hinged Iron Arch.* By J. H. Cunningham. Gives description, with details, of a three-hinged, wrought-iron arch constructed at Claremont, Ia. *Engineering*, Aug. 12, 1887.
- , *Torkham, India.* Describes the method employed to launch three short spans of riveted girder of Torkham bridge. Illustrated. *Indian Engineering*, Oct. 1, 1887; *Eng. News*, Nov. 19, 1887; *Engineering*, Jan. 13, 1888.
- , *Tay.* By Peter Barlow, before the Institution of Civil Engineers. Gives principal dimensions and general data of the Tay viaduct. *Sci. Am. Suppl.*, June 16, 1888.
- , —. By Wm. Ingliss, before the Institution of Civil Engineers. Gives details of the construction and difficulties overcome of the Tay viaduct. *Sci. Am. Suppl.*, June 16, 1888; *R. R. Gazette*, June 29, 1888.
- , *Wells Street, Chicago, Removal of the.* Gives details of the moving of the

- Wells street draw-bridge, bodily, to its new position on Dearborn street. *Engin. and Build. Rec.*, April 14, 1888.
- Bridge, Willamette River, Oregon.** Gives elevation, cross section and details of a timber Howe truss across the Willamette River, Albany, Oregon. It has two spans 175 feet long, and a draw span 260 feet in length. *Engineering* Jan. 6, 1888; *Sci. Am. Suppl.*, March 17, 1887.
- Bridges, A New Truss.** By Geo. H. Pegram. Proposes a new form of truss. Gives formulae and applies them to a through span of 255 ft., etc. Valuable. *Eng. News*, Dec. 10, 1887.
- , *A Review of.* By Prof. W. P. Trowbridge. Of the development of bridge construction, with notices of some remarkable historic bridges. *Sci. Am. Supple.*, March 17, 1887.
- , *Economical Height of Trusses for a Given Panel Width.* By John Lundie. *Jour. Assoc. Engrs. Soc.*, Vol. VII., pp. 101-103 (March, 1888).
- , *Failures.* By G. H. Thomson, before the Bath meeting of the British Association. Discusses bridge failures and their causes, and details of experiments made on various types of bridges. *R. R. Gazette*, Sept. 28, 1888.
- , *Guard Rails on.* A circular issued by the Massachusetts Board of Railroad Commissioners to all of the railroads in that State, recommending a certain form of guard rail on bridges. *R. R. Gazette*, Dec. 30; *Eng. News*, Dec. 31; *Eng. and Building Record*, Dec. 31.
- , *Highway.* By S. A. Buchanan. Discusses the construction, maintenance and repairs of short span highway bridges. *Rpt. Ohio Soc. Surv. and Eng.*, 1888, pp. 184-194.
- , *Highway.* By J. O. Wright. Discusses the present practice of building highway bridges and gives hints for improvements. *Rpt. Ill. Soc. Engrs. & Surveyors*, 1888, pp. 60-65.
- , *Highway, Computation of Strains in.* By C. M. Brown. A paper showing county commissioners and surveyors how to compute strains in highway bridge structures. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 195-203.
- , *Highway, Improved.* By J. H. Burnham. Discusses the improvements made in highway bridges. The discussion on the paper relates mostly to the use of brick in place of stone. *Rpt. Ill. Soc. Engrs. & Surveyors*, 1888, pp. 47-54.
- , *Highway, General Specifications for, of Iron and Steel.* By J. A. L. Waddell. Discusses the present practice with its evils, and gives suggestions for better methods. Address the author, Kansas City, Mo.
- , *Long Span, Discussion of.* By Gustav Lindenthal. Gives a discussion of cantilever, general features of arch bridge and suspended arches. *Eng. News*, March 3, 1888.
- , *Pile and Trestle.* By A. F. Robinson. Discusses the use of pile and trestle bridges, and gives design of the standard trestle of the Chicago, Burlington & Northern Railroad Company. *Eng. News*, April 7, 1888.
- , *Specifications for Iron.* By I. O. Baker. Gives specifications relating to ultimate strength, elongation and fractured area. *Rpt. Ill. Soc. Engrs. and Surv.*, 1888, pp. 55-57.
- , *Steel for.* See Steel.
- , See Trestles, Draw-bridges, road bed and floor beams.
- , *Test of Full-size Floor Beam.* By A. P. Boller. A paper before the American Society of Civil Engineers, giving details of the testing of a full-sized wrought-iron double track floor beam. Abstracted *Sci. Am. Supple.*, June 2, 1888.
- , *Types of Iron Girder, Indian Midland R. R.* A series of plates giving elevations, plans and details of types of iron girder in use on the Indian Midland R. R., India. *Indian Engineering*, Aug. 25, et seq., 1888.
- , *Upright Arched.* By J. B. Eads. Endeavors to show that upright arched bridges can be more economically constructed than is possible by any other method. *Trans. Am. Soc. C. E.*, Vol. III., 1874, pp. 195-238.
- Bridge Floors, Design, Strength and Cost.** By Edmund Olander, before the Society of Engineers. Gives a comparison of weight, strength and cost of various designs of bridge floors. Four plates. *Trans. Soc. Engrs.*, 1888, pp. 27-67.
- , *Street.* By Carl Gayler, before the St. Louis Engineers' Club. Discusses the different kinds of floors in use and gives cost of the different classes used in St. Louis. *Jour. Asso. Engin. Soc.*, May, 1888; *Engin. and Build. Rec.*, June 30, 1888.

- Bridge Inspection.** Gives the order to bridge inspectors in use on the Buffalo, Rochester & Pittsburgh Railroad. *Engin. News*, May 12, 1888.
- , *Inspection and Maintenance of.* A discussion at the annual convention of the American Society of Civil Engineers on the inspection and maintenance of railway structures. The discussion, by many prominent engineers, covers 50 pages in the *Trans. Am. Soc. C. E.*, Vol. XVII., December, 1887.
- , *Selection and Maintenance of.* By D. W. Mead. Gives hints relating to the selection and maintenance of bridges for cities. *Rep. Ill. Soc. Engrs. and Surveyors*, 1888, pp. 65-68.
- *Pins and Eye Bars, Proportion of.* By C. F. Stowell. Discusses the present state of pin calculation and gives formula for computing the stress in the side of the head of eye-bars. *Engr. News*, March 31, 1888.
- Bridge Strains, Slide Moment Diagram for Computing.** By J. E. Greiner, before the Engineers' Society of Western Pennsylvania. Gives a description of a slide moment diagram, which has been in use in the Baltimore & Ohio office for three years, and is considered the best method of finding shears and moments in bridges. Abstracted in *Engin. News*, April 14, 1888.
- Bridges, Stresses in Lattice, New Method of Obtaining.** By Wm. Robertson. Gives a new geographical method of computing the strains in lattice bridges. *Engineer*, Dec. 30, 1887. *Sci. Am. Supple.*, March 24, 1888.
- , *Graphical Evolution of Stress in Lattice Girders.* By Wm. Robertson. Gives a comparison between the values of the stresses in the flanges of various forms of latticing as determined by their numerical evolution and the ordinate to the parabolic curves of moments, and deduces rules for graphical solution. *Engineer*, March 16, 1888.
- Bridge Work and Inspectors.** By S. T. Wagner, before the Annual Convention of the American Society of Civil Engineers. Discusses the characteristics and work of bridge inspectors and makes suggestions for their work. Discussion. *Trans. Am. Soc. C. E.*, Vol. XVII., December, 1887, pp. 319-329.
- Building Materials and their use in Fire-Proof Construction.** By S. E. Loring. An illustrated series describing the best and latest practice in the construction of fire-proof buildings. *Building*, Dec. 17, 1887, *et seq.*
- Buildings, Steel Plate.** Detailed plans and descriptions of a method of constructing buildings with embossed galvanized steel plates. *Sci. Am. Supple.*, Nov. 5, 1887.
- Cables, Chain.** A full discussion of the determination of the character of iron best adapted for chain cables, the best form and proportions of links, with details of the testing of a large number of specimens. *Report U. S. Board on Testing*, Vol. I., 1881, pp. 1-238.
- , *Steel.* Abstracts from the specifications for the steel cables for Birmingham cable roads. *Engineer*, Aug. 12, 1887.
- Cable Railroad, East River Bridge.** By G. Leverich, before the American Society of Civil Engineers. Gives a very complete description of the road, plant and particulars of traffic and operation, details of wear, renewals and changes, with 28 plates showing details. Very valuable. *Trans. Am. Soc. of C. E.*, Vol. XVII. (March, 1888), pp. 67-102.
- Cable Roads, Birmingham, Eng.** Gives a brief description, with a two-page detailed drawing, of the Birmingham cable road. *Engineer*, June 22, 1888.
- , *Edinburgh.* Gives constructive details of the Edinburgh Northern Cable Tramway, with description. *Engineer*, Oct. 28, Nov. 4 and 11, 1887.
- , *Otto System.* Describes the installation prepared for the New Castle Exhibition, with illustrations showing details. *Engineering*, April 6, 1888.
- Canal, Manchester Ship.** A series of articles describing in detail the progress made and methods employed in the construction of the Manchester ship canal. *Engineering*, May 18, *et seq.*, 1888. Abstracted *Eng. News*, June 30, *et seq.*, 1888. *Engin. and Build. Rec.*, Sept. 29, *et seq.*, 1888.
- , *Manchester Ship.* Gives brief review of the above project, with particulars of the work to be done and methods of operation. *R. R. Gazette*, Sept. 14, 1888.
- , *Manchester Ship, Plant and Machinery.* By L. B. Wells, before the Bath meeting British Association. Gives a brief description of the principal machinery now in use on the Manchester Ship Canal. *Engineer*, Sept. 21, 1888.
- , *Nicaragua, Location of,* 1888. Gives maps showing results of the survey of the

- Nicaragua Canal during 1888, with full description of the work to be done. *Engin. News*, July 14, 1888.
- Canal, Nicaragua, Recent Surveys of.** By R. E. Perry, before the American Association for the Advancement of Science at Cleveland. Gives details of the surveys and their results. Abstracted in *Engr. News*, Aug. 18, 1888.
- , *Panama.* An abstract of an article in *Le Genie Civil*, giving profile of the proposed canal, with locks. *Engin. News*, Feb. 11, 1883.
- , *Panama, Actual Status of the.* Gives a carefully prepared article, with official profile and cuts from photographs, showing the actual condition of the work. *Engr. News*, June 2, et seq., 1888.
- , *Panama, and its Rivals.* By J. S. Jeans, before the Society of Arts. Gives a brief review of the historical, engineering and commercial aspects of the Panama and Nicaragua canals. *Jour. Soc. Arts*, April 6, 1888.
- , *Panama in 1887.* By Lieut. C. C. Rogers, before the American Society of Civil Engineers. Gives details of the condition of the canal as seen during an inspection trip of nearly three weeks during March and April, 1887. Abstracted *Engin. and Build. Rec.*, Jan. 28, 1888.
- , *Panama, Plant and Machinery of the.* By Wm. P. Williams, before the Annual Convention of the American Society of Civil Engineers. Gives results of investigation of the methods and plant used on the Panama Canal. *Engr. News*, Aug. 18, 1888.
- , *Panama, Proposed Locks on the.* Gives a description, with general view, of the proposed locks on the Panama Canal. There are to be four locks, two of 8 m. and two of 11 m. lift on the Atlantic side, and three of 11 m. and one of 8 m. lift on the Pacific side. They are to be 13 by 13 m. *Le Genie Civil*, Feb. 18, 1888; *Engr. News*, March 10, 1888; *Engr. and Build. Rec.*, March 10, 1888; *Sci. Am. Supple.*, March 31, 1888.
- , *Panama, Work on the.* Gives a good statement of what has been done up to the present time. Illustrated. *Sci. Am. Supple.*, March 10, 1888.
- , *Tancarville, France.* Gives brief description of the canal being constructed between Havre and the Seine. *Sci. Am. Supple.*, Sept. 15, 1888.
- , *and Inland Navigation.* By W. J. C. Moens, before the Society of Arts Canal Conference. Gives much information relative to inland navigation in France, Belgium and Holland. *Jour. Soc. Arts*, June 8, 1888.
- , *Improvement of, Communication.* By Sam. Lloyd, before the Canal Conference of the Society of Arts. *Jour. Soc. Arts*, July 8, 1888.
- , *Improvement of, between London and Birmingham.* By Henry J. Marten. Gives details of the methods proposed for improving the efficiency and economy of the canals between London and Birmingham. *Jour. Soc. Arts*, June 1, 1888.
- , *Laws of.* By A. B. Kempe, before the Society of Arts Canal Conference. Object of the paper is to give a concise statement of the existing laws relating to canals in England. *Jour. Soc. Arts*, July 8, 1888.
- , *and Inland Navigation National Works.* By Gen. Randall, before the Society of Arts Canal Conference. Advocates the control of canals by the Government as national works. *Jour. Soc. Arts*, June 1, 1888.
- , *and Railroads, Transport by.* By G. Lester, before the Society of Arts Canal Conference. *Jour. Soc. Arts*, June 1, 1888.
- , *Great Britain.* By M. B. Cotsworth, before the Society of Arts Canal Conference. Gives the history, use and progress of canal and river navigation in England and Ireland. *Jour. Soc. Arts*, May 25, 1888.
- , *Inland Transportation in the 19th Century.* By F. R. Conder, before the Society of Arts Canal Conference. Discusses transportation in England by land and water, and shows how the canals have been taken in hand by the railroad at a loss. *Jour. Soc. Arts*, June 1, 1888.
- , See Inland Navigation.
- , *Maintenance of.* By G. R. Jebb, before the Society of Arts Canal Conference. Discusses the work of a canal, method of maintaining them, with remarks on the special difficulties to be overcome in mining districts. *Jour. Soc. Arts*, May 25, 1888.
- , *Waterway between Lake Michigan and Illinois River, by way of the Illinois River.* By R. E. McMath, before the Engineers' Club of St. Louis. Discusses the proposed waterway from a St. Louis point of view in respect to its physical,

- sanitary, economical and political consequences. *Jour. Assoc. Engin. Soc.*, August, 1888, Vol. VII., pp. 313-329.
- Canal Conference, Society of Arts.** At a conference recently held under the auspices of the Society of Arts, fifteen papers on canals and inland navigation were presented. They cover the use, history, progress and present condition of canals, their influence on railroads, and a comparison of the costs of traffic on each. *Jour. Soc. Arts*, May 28, *et seq.*, 1888.
- Canal Engineering.** By L. F. Vernon-Harcourt, before the Society of Arts Canal Conference. Treats of the past, future aims and the prospects of canal engineering in the future. *Jour. Soc. Arts*, May 25, 1888.
- Canal Lift, Fontinettes, France.** Gives a discussion on canal lifts vs. locks, and a description, with view, of the hydraulic lift at Fontinettes, France. *R. R. Gazette*, Sept. 21, 1888; *Engr. & Mining Jour.*, Sept. 29, 1888.
- Car, Coal, 60,000 lbs. Capacity.** Gives drawings of a 60,000 lbs. capacity coal car for the Georgia Pacific Railroad. *Nat. Car and Loco. Builder*, June, 1888.
- , *Standard 50,000 lbs.* Gives detailed drawing and specification of a standard 50,000 lbs. box car, for the Minneapolis, Sault Ste. Marie & Atlantic Railroad. *Master Mechanic*, November, 1888.
- , *Standard 50,000-lb. Freight.* Gives brief description with drawings and bill of material, of the standard 50,000-lb freight car of the Lehigh Valley Railroad. *R. R. Gazette*, June 8, 1888.
- , *Standard 50,000-lb Gondola.* Gives detailed drawing, with abstract from specification for the standard 25-ton gondola car of the Newport News & Mississippi Valley Co. *R. R. Gazette*, April 6, 1888.
- , *Twin Hopper 60,000-lb. Gondola.* Gives description, with bill of lumber and detailed drawing, with dimensions, of a twin hopper bottom gondola car having a capacity of 60,000 lbs. recently constructed for the Lehigh Valley Railroad. *R. R. Gazette*, Sept. 14, 1888.
- , *50,000-lb. Box, C., B. & Q. R. R.* Gives plan, elevation and cross-section, with full dimensions, of the 50,000-lb. box-car in use on the Chicago, Burlington & Quincy Railroad. *Master Mechanic*, October, 1888.
- , *Twenty-five Ton Iron Ore.* Gives a two-page plate of detailed drawings of a twenty-five ton iron ore car used on the Swedish Railroad. *Engineer*, April 27, 1888.
- , *100,000-lb. Car, Penn. R.R.* Gives drawing, showing details of a car of 100,000 lbs. capacity, designed for carrying cables for street railroads, and built for the Pennsylvania Railroad. *R. R. Gazette*, May 11, 1888.
- Cars, Canada's Cattle.** Gives description, with plans, elevation and cross-section, of Canada's cattle cars. They are provided with hayracks, water-troughs and movable partitions. *R. R. Gazette*, March 2, 1888.
- , *Six-Wheel Trucks for Freight.* By J. M. Barr, before the March meeting of the Western Railroad Club. Discusses the use of the collarless axle, and advocates the use of six-wheel trucks for freight cars of 60,000 lbs. capacity. *Master Mechanic*, April, 1888; *R. R. Gazette*, March 23, 1888; *Nat. Car and Loco. Builder*, April, 1888.
- Car Axles, Bearings and Lubricants.** Summary of the discussion of the above subjects by the New England Railroad Club. *Railroad Gazette*, Nov. 18, 1887; also *Nat. Car and Loco. Builder*, December, 1887.
- Car Couplers.** Gives the contour lines, length of draw-bar and arrangement of dead-block for the automatic coupler, as established by the committee of the Master Car-Builders' Association. *R. R. Gazette*, April 20, 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.
- Car Heating.** A very good review of the different systems for heating cars by means of steam from the locomotive. By W. A. Smith, before the December meeting of the Western Railway Club. Illustrated by cuts of the different styles of couplings. *Master Mechanic*, Jan., 1888, also *Am. Engr.*, Dec. 28, 1887.
- , *Gold System.* Gives illustrated description of the Gold system adapted to the Baker heater. *Railroad Gazette*, Dec. 16, 1887.
- , *Sewall System.* By C. P. Karr. A very full description of the system, with drawings showing details, coupling, traps, etc. *Sci. Am. Sup.*, Dec. 24, 1887; *R. R. Gazette*, Jan. 20, 1888.
- , *Couplers for Steam.* Brief description, with drawing, of nearly all the different

- forms of coupling now in use for continuous heating of cars by steam from the locomotive. *R. R. Gazette*, Dec. 2, 1887; *Engineer*, Jan. 27, 1888.
- Car Heating, Couplers for Steam.** A very full discussion of the subject by the New York Railroad Club. *Master Mechanic*, May, 1888.
- , *in Germany and Sweden.* Gives good description of the practice of heating cars by steam in Germany and Sweden. *Mast. Mechanic*, Nov., 1887.
- , *Steam.* A paper by Prof. Lanza, before the April meeting of the New England Railroad Club. Giving details of experiments made to determine the amount of steam used in heating passenger cars, with discussion. *R. R. Gazette*, April 20 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.
- , *Steam.* Gives tabulated results of experiments in continuous heating, from reports collected by the Committee of the Master Car-Builders' Association. *R. R. Gazette*, June 22, 1888; *Engin. News*, June 30, 1888.
- , *Steam on the C., M. & St. P. R. R.* Gives description and detailed drawings of the couplings of the Gibbs system of steam heating now being tested on the C., M. & St. P. R. R. *R. R. Gazette*, Jan. 13, 1888; *Engin. and Build. Rec.*, Jan. 21, 1888.
- , *Steam, Notes on.* By W. F. Baldwin. A paper before the American Society of Mechanical Engineers. Gives experience gained while making experiments on the Long Island Railroad. *Engin. and Build. Rec.*, May 12, 1888; *Am. Eng.*, June 20, 1888; *Engin. News*, Aug. 18, 1888.
- , *Test of the McElroy System.* Gives details of test of McElroy system of continuous heating made on the Hudson River Railroad. *R. R. Gazette*, April 6, 1888.
- , *Winters Lesson in Steam.* By Geo. Gibbs, before the April meeting Western Railroad Club. Discusses steam heating in the light of the experience of the past winter. *Master Mechanic*, May, 1888; *Nat. Car. and Loco. Builder*, May, 1888; *R. R. Gazette*, April 29, 1888.
- Car Wheels.** Three valuable papers presented to the February meeting of the New York Railroad Club, on the guarantee for car wheels, mileage of steel-tired wheels and the safety of cast-iron wheels. *Master Mechanic*, March, 1888; *R. R. Gazette*, Feb. 24, 1888.
- , *and Axles. Their Relation to the Track.* A discussion by the members of the New England Railroad Club at its February meeting. Relates mainly to the relative merits of steel and cast-iron wheels. *Master Mechanic*, March, 1888; *R. R. Gazette*, Feb. 17, 1888; *Nat. Car & Loco. Build.*, March, 1888.
- , *and Tires.* By C. F. Allen, before the March meeting of the New England Railroad Club. Discusses the question of safety in the use of wheels and tires. Followed by discussion. *Master Mechanic*, April, 1888; *Nat. Car and Loco. Builder*, April, 1888; *R. R. Gazette*, March 23, 1888.
- , *Specifications for Cast-Iron.* Gives specifications for cast-iron car wheels, as proposed by Mr. Barr before the Western Railway Club. *R. R. Gaz.*, Dec. 23 1887; *Mast. Mechanic*, January, 1888.
- , *Steel Tired and Chilled.* Extract from the report of the Massachusetts Railroad Commissioners on the Haverhill accident, showing the kind of wheels in use in Massachusetts. *R. R. Gazette*, May 11, 1888; *Nat. Car & Loco. Builder*, June 1888; *Engin. News*, May 19, 1888.
- Castings. New Process of Making Ornamental Castings.** Consists in lining the inside of the mould with carbonized lace or other, textile fabric. Abstract of remarks made at the meeting of the Franklin Institute, April 20, 1887. By A. E. Outerbridge, Jr. *Journal of the Franklin Institute*, June, 1887, Vol. CXXIII., No. 738. Report of Franklin Institute Committee on same. *Journal of Franklin Institute*, November, 1887, Vol. CXXIV., No. 743.
- Cement and Mortar, Selection, Inspection and Use of.** By S. F. Burnett, before the Engineers' Club of St. Louis. Gives practical hints in regard to the selection, inspection and action of cement and sand, and the methods of mixing and using to produce a good mortar. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 258-264.
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- , *Hardening of.* A series of articles embodying the results obtained in the most recent and important investigation on the hardening of cements. The subject is treated from a chemical point of view. *Engineer*, Sept. 21, *et seq.*, 1888.
- , *How to Test the Strength of.* By J. Sondericker. Gives a description of an apparatus for testing cements, and presents some of the results obtained. *Jour. Assoc. Engin. Soc.*, June, 1888, Vol. VII., pp. 207-222. Also *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 172-184.
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- , *Portland, Improvements in the Manufacture of.* By Frederick Ransome. A paper before the British Association, giving the latest and most advanced method of manufacture. *Engineer*, Sept. 9, 1887; *Sci. Am. Sup.*, Nov. 19, 1887.
- , *Portland, Testing.* By H. Farja, before the American Society of Civil Engineers. Gives details of the method employed by himself for a number of years; shows details of apparatus for mixing and testing cements. *Trans. Am. Soc. C. E.*, Vol. XVII. (November, 1887), pp. 218-228.
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- , *for use in Public Works.* An abstract of a report by the Executive Board of the City of Rochester, N. Y., prepared by Emil Kurchling. *Engin. and Build. Rec.*, March 24, *et seq.*, 1888.
- , *Strength of.* By Prof. I. O. Baker. Gives tables showing the strength of cement mortar of various ages, compiled from a large number of experiments. *Eng. and Building Rec.*, May 5, 1888.
- Cement Tests.** By J. E. Codman before the Philadelphia Engineers' Club. Gives results of testing cement in different forms of briquettes. *Proc. Engs. Club*, Philadelphia, Dec., 1887, Vol. VI., pp. 168-172.
- , *New Croton Aqueduct.* Gives profile showing strength of cements used in the construction of the new Croton Aqueduct. *Engin. and Build. Rec.*, Aug. 18, 1888.
- Chain Cable.** Discussion of its strength, weakness, weld, steel, weight and method of reducing it without a proportional loss of strength, details of tests, etc. *Report of U. S. Board on Testing, etc.*, Vol. I., 1881, pp. 149-210.
- Chart.** *The Pilot Chart of the North Atlantic Ocean.* Lecture before the Franklin

- Institute, by Everett Hayden, of the United States Hydrographic Office. Presents a copy of the pilot chart for March, 1888, and interesting description of it. *Journal of the Franklin Institute*, April and May, 1888.
- Chimney.** Gives notes on the construction of a large chimney, being an iron frame lined with brick. *Sci. Am. Supple.*, Dec. 10, 1887. *Engineer*, Jan. 6, 1887.
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- Combustion.** A good article for practical men. *Engineer*, Aug. 19, 1887.
- , *Natural and Forced Draught.* By W. G. Spence before the Northeast Coast Institution. A valuable paper giving the results of experiments with forced and natural draughts. *Engineering*, Feb. 10, et seq., 1888. An editorial on the above paper, *Engineer*, Feb. 10, 1888, and the article Feb. 17, 1888.
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- Concrete.** By John Lundie. Gives notes on the selection of material, mixing and depositing concrete in place. *Jour. Assoc. Eng. Soc.*, December, 1887, Vol. VI., pp. 437-440. *Sci. Am. Supple.*, April 28, 1888. *Mechanical World*, May 12 and 19, 1888.
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- , *in Sea Water.* An abstract from the report of P. J. Messent to the Aberdeen Harbor Board. Gives as a cause for the failure of some of the concrete work at the Aberdeen Graving dock, injudicious specification for the cement or improper method of mixing or using it. *Engineering*, Jan. 28, 1888.
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- Contour Lines.** By B. Feind. *Jour. Assoc. Engr. Soc.*, Vol. VII., pp. 89-92. (March, 1888.)

- Contract, Standard Building.** Gives text of a standard building contract, the adoption of which is advised by the Committee of Conference of the American Institute of Architects, the Western Association of Architects and the National Association of Builders. *Engin. & Build. Rec.*, Sept. 15, 1888.
- Copper, Analysis of.** By A. A. Blair. A paper giving the methods used for the analysis of copper. *Report of Board on Testing, etc.*, 1881, Vol. I., pp. 247-266.
- , *Influence on Steel.* See Steel.
- Covered Way, Glasgow City and District Railroad.** By W. S. Wilson, before the Institution of Civil Engineers. Gives details of the construction of a covered way of which 2,600 yards were in tunnel. *Proc. Inst. C. E.*, Vol. XCII., pp. 288-291; *Engin. & Build. Rec.*, June 23, 1888.
- Crane, "Goliath," Twelve Ton Steam.** Gives a two-page plate showing details of a twelve-ton steam traveling crane. It has a span of 60 feet, and a clear height of 28 feet. *Engineering*, Jan. 13, 1888.
- , *Traveling.* Gives a description, with full details, of a six-ton universal traveling crane for the erection of the Union Elevated Railroad, Brooklyn. *San. Engr.*, Dec. 17, 1887.
- , *Traveling.* An illustrated description of a traveling crane, 50 feet span, to lift three tons. *Engineer*, Sept. 9, 1887.
- Cranes.** Drawings of a twenty-five-ton wharf crane and a three-ton locomotive crane in *Engineer*, April 6, 1888.
- , *Water, for Indian Railroads.* Gives brief description and full detailed drawing of water cranes to be used on the Indian State railways. *Engineer*, Oct. 7, 1887.
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- Culvert, Railroad.** By E. A. Hill. Gives details of the building of a culvert for the drainage of about 1,600 acres of land; shows plans, cost, etc. *Report Ill. Soc. Engrs. and Surveyors*, 1888, pp. 28-42. *R. R. Gazette*, May 25, 1888. A continuation of the above discussion by Mr. Hill in *R. R. Gazette*, Nov. 2, 1888.
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- , *Gileppe.* By A. Marichal. Gives a brief description of the curved masonry dam near Verviers, Belgium. Illustrated. *Proc. Engr. Club, Philadelphia*, Vol. VI., pp. 243-246.
- , *Mill River, Failure of the.* Gives report of a committee appointed to report upon the failure of a dam on Mill River, at Williamsburg, Mass. *Trans. Am. Soc. C. E.*, Vol. III., pp. 118-122.
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- , *Quaker Bridge, History of the.* By E. E. R. Tratman. Gives a good review of early history of Quaker Bridge dam and the reasons for its adoption. Illustrated by maps, etc., from the Report of the Aqueduct Commissioner. *Engineer*, Jan. 27, 1888.
- , *Quaker Bridge. Plan formation of.* By A. Marichal before the Philadelphia Engineers' Club. Discusses the question whether the dams should be built with a curved or straight line and advocates the former. *Am. Engr.*, Jan. 18, 1888.
- , *Sweetwater.* By J. D. Schuyler, before the American Society of Civil Engineers. Gives details of the construction of the Sweetwater dam, San Diego, Cal. *Engr. News*, Oct. 27, 1888.
- , *Walnut Grove.* Gives views, sketch plan and details of construction of the Walnut Grove "rock fill" dam, near Prescott, Ariz. *Engr. News*, Oct. 20, 1888.
- , *Masonry.* By J. W. Hill. A paper before the American Society of Civil Engineers. Gives description of the masonry dam at Eden Reservoir, Cincinnati, and shows the methods of computation used, with discussion and three plates. *Trans. Am. Soc. C. E.*, Vol. XVI., pp. 261-282, June, 1887.

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- , *High Masonry, Profile of.* By Isaac Morley. Derives a formula for determining the profiles of high masonry dams and discusses its application. *Engin. News*, Aug. 11, 1888.
- , *High Masonry, Theory of.* A reprint of the report of Mr. B. S. Church to the Aqueduct Commission on the design of the Quaker Bridge dam. Gives a comparison of all of the great masonry dams of the world, with plates of cross-sections and plans of the same; also tables of data, etc. A valuable article. *Engin. News*, Jan. 7 and 14, 1887; *Engineer*, March 20, 1888.
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- Disinfection** Describes the machines used for disinfecting clothing, bedding, etc., by means of hot air and steam, acting separately and in combination. *Engineer*, May 11, *et seq.*, 1888; *Sci. Am. Supple.*, June 30, 1888.
- Disinfectant, Aero Steam.** A disinfectant in which all articles are subject to a moist heat of at least 213° Fah. *Engineer*, July 29, 1887.
- Dock, Alexandra, Hull.** By A. C. Hurtzig before the Institution of Civil Engineers. Gives details of the construction of the Alexandra Dock, 1881-5. The work included a dock of 46½ acres, two miles of dock wall, two graving docks, a lock 550 × 85 feet; embankment, 40 feet high and 6,000 feet long, and dredging an artificial channel. *Proc. Institute C. E.*, Vol. XCII., pp. 144-186. Abstracted *Engineering*, Feb. 10, 1888. Abstracted *Mech. World*, Feb. 18, 1888. Abstracted *Engineer*, March 2, 1888.
- , *Esquimalt.* Gives description of the new dock at Esquimalt, British Columbia, with two two-paged plates showing plans and details of the work. The dock is 451 feet long, 65 feet wide at the entrance, and has 27 feet of water on the sills. *Engineering*, July 20 and 27, 1888.
- , *Dry, Havre.* Full description, with plan, transverse section and views of the work of the large dry-dock being built at Havre, France. *Le Genie Civil*, Oct. 29, 1887; *San. Engr.*, Dec. 3, 1887.
- , *Hydraulic Lift, Bombay.* Brief description of the hydraulic lift dock at Bombay. It is the largest hydraulic structure in the world; is 350 ft. long, 88 ft. clear width, and docks vessels drawing 30 ft. *Engineering*, Nov. 25, 1887.
- , *Preston and River Ribble.* Gives history of the work of constructing a 40 acre dock at Preston. Eng., and the improvement of the river Ribble. *Engineer*, Sept. 30, 1887.
- , *Pontoons and Floating.* By Alex. Taylor, before the northeast coast Institution of Engineers and Shipbuilders. Gives approved practice for pontoons and floating docks. *Sci. Am. Supple.*, July 7, 1888.
- Drainage, Land.** A paper by E. B. Opdyck, on the construction, comparative cost and efficiency of tile drains and open ditches. *Rpt. Ohio Soc. Surr. and Engs.*, 1888, pp. 148-155.
- , *Newhaven.* Brief description, with details, of the drainage work at the Port Newhaven, Eng. *Engineer*, July 29, 1887.
- Drainage Tables.** By G. H. Johnson. Gives tables showing the diameters of circular pipes of given length which will discharge given volumes of water per second under a given head. *Eng. News*, May 5 and 12, 1888.
- Draw-Bridge, Milwaukee.** Description of a 203-foot span double-track draw-bridge at Milwaukee. Cuts showing details. *San. Engr.*, Nov. 26, 1887.

- Draw-Bridges.** By Clemens Herschel. Treats on the principles of construction of and the calculation of the strains in revolving draw-bridges having two spans as openings and built as continuous girders, more especially as continuous panel girders. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 395-448.
- See Bridge.
- Draw-Spans and their Turn-Tables.** By C. Shaler Smith. A paper for "non-specialists," showing method of computing the strains; also, gives table of draw-bridge tests to obtain co-efficient of rolling friction. *Trans. Am. Soc. C. E.*, Vol. III., pp. 129-141.
- Drawings, Cyanotype Process of Reproducing.** Gives notes compiled in the Photographic Office Survey of India Department, Calcutta, on the positive cyanotype process of reproducing drawings with dark lines on a clear ground. *Indian Engineering*, Aug. 4, 1888.
- , *Duplication of.* By J. M. Bradford. Describes the "blue prints" method, with formula. *Rept. Ohio Soc. Surr. and Engrs.*, 1888, pp. 250-261.
- Dredge, Double Ladder, Swansea Harbor Trust.** Gives brief description, with two-paged plate, showing plan, sectional elevation and sections, of a double ladder dredge recently constructed for the Swansea Harbor Trust. Dimensions, 150 × 41, with 12 hold; capacity 900 tons per hour from a depth of 38 feet. *Engineering*, July 13, 1888.
- *Ejector*, using compressed air as power to set column of water in motion. *Annales des P. & C.*, June, 1888.
- , *Rock, Suez Canal.* An illustrated description of the sub-aqueous rock dredger "Dérocheuse," built for the Suez Canal. Its dimensions are 180 × 40 × 12 ft. It has ten chisel bars 42 ft. long, weighing four tons each, and dredging machinery to remove the broken rock. Its capacity is about 40 tons per hour. *Engineer*, March 9, 1888.
- Drilling, Relative Economy of Hand and Machine.** By W. A. Wheeler. Gives a valuable comparison of the cost of hand and machine work from a purely economical standpoint. Shows there is but little difference in the cost. *Jour. Assoc. Engr. Soc.*, February, 1888.
- Driven Wells as a Source of Water Supply for Cities.** By Albert F. Noyes. A valuable contribution to the subject, giving many important facts and generalizations. *Jour. New Eng. W. Works Assoc.*, June, 1887.
- Dynamo, Eickmeyer's.** A new departure in dynamo construction, presenting apparently some marked advantages. The field coils surround the armature, and a new and ingenious method of winding the latter is described. *Electrical Engineer*, March, 1888; *Tel. Jour. and Elec. Rev.*, March 23, 1888.
- , *Morley's Alternating Current.* Gives an illustrated description of Morley's new alternating current dynamo. It has fixed armatures and revolving magnets. *Tel. Jour. and Elec. Rev.*, June 1, 1888; *Sci. Am. Supple.*, July 21, 1888.
- Dynamo Machines, A Synthetic Study of.** A series of articles giving a full synthetic study of dynamo machines, including a good exposition of induction. *T. J. and Elec. Rev.*, Aug. 3, 1888.
- Dynamo-Electric and Electro-Dynamo Machinery, Design and Construction of.** Read before the Engineers' Club of St. Louis, Feb. 16, 1887, by Dr. Wellington Adams. Applies the formulæ of Kapp to the design of an efficient dynamo. *The Electrician and Electrical Engineer*, Dec., 1887.
- Dynamos and Motors, Designing and Calculating.** The most practical method of designing and proportioning dynamos yet published. Francis R. Crocker. *Electrical World*, April 28, 1888.
- Dynamometer, French Transmission.** Gives a description of a dynamometer constructed and used to determine the efficiency of a plant for the transmission of power by electricity. *Engineer*, Feb. 17, 1888.
- Earthwork. Filling South Boston Flats.** By F. W. Hodgdon. Gives details of the methods employed by the Commonwealth of Massachusetts to fill 120 acres of South Boston Flats from two feet below to thirteen feet above mean low water. *Jour. Assoc. Eng. Soc.*, January, 1888, pp. 5-9.
- , *Formula for.* Gives a new formula, derived from the prismoidal formulæ, for computing railroad earthwork. It also has a graphical representation. *Engin. News*, July 28, 1888.
- Economy of Structures, Comparison of the.** By Prof. G. F. Swain, before the New

- England Water-Works Association. Discusses the proper method of comparing the economy of structures of different classes. *Jour. N. Eng. W.-Works Assoc.*, March, 1888, Vol. II., pp. 31-34.
- Electric Balance**, *Thomson Composite*. By Thomas Gray. Full description of Sir Wm. Thomson's new balance, available as volt, ampere, or watt-meter. *Sci. Am. Suppl.*, July 14, 1888.
- Electric Batteries**. *The Possibilities and Limitations of Chemical Generators of Electricity*. A paper read before the Am. Inst. of Electrical Engineers, May 16, 1888, by Francis B. Crocker. Shows what can be expected of any given combination of materials, and gives table of the cost per horse-power per hour of voltaic battery energy, with different materials. *Electrical World*, May 26, 1888; *Electrical Engineer*, June, 1888.
- Electric Furnaces**. By E. J. Houston. Describes some of the early electric furnaces. *Tel. Jour. and Elec. Rev.*, April 6, 1888.
- Electrical Lighting**. *Applied upon the Suez Canal*. By R. Percy Sellon before the Mechanical Science Section of the British Association for the Advancement of Science. Describes the use of the electric light on the Suez Canal, and gives text of the regulation issued by the canal company. *T. J. and Elec. Review*, Sept. 14, 1888.
- Electric Lighting**. *Cost of Arc Lighting*. A paper read by C. M. Keller before the Western Gas Association, giving the running expenses for a number of cases for Thomson-Houston and American arc lights. *Progressive Age*, June, 1888.
- Electric Lighting**. *Efficiency of Incandescent Lamps*. By W. E. Ayrtton and J. Perry. Before the Physical Society of London. Treats of the efficiency of incandescent lamps with direct and alternating currents. The mean of 75 experiments gave same results for both. *Tel. Jour. & Elec. Rev.*, June 1, 1888.
- *in America*. By Prof. Geo. Forbes, before the Mechanical Science Section of the British Association for the Advancement of Science. Compares the present state of the central system of lighting with its condition four years ago. Also compares the state of the system in the United States with that of England. *Tel. Jour. and Elec. Review*, Sept. 14, 1888.
- *Independent Engines*. A paper before the American National Electric Light Association, by William L. Church, discussing the advantages of independent engines over the system of concentrated power for incandescent lighting. *Tel. Jour. and Elec. Rev.*, April 13, 1888.
- *Maximum Efficiency of Incandescent Lamps*. A paper read before the American Institute of Electrical Engineers, April 10, 1888, by John W. Howell. A valuable contribution to electric lighting literature. Illustrates how to determine at what candle-power it is most economical to operate any given lamp, and determines for a particular Edison lamp that it is working at its maximum efficiency when the cost of the lamp is 15 per cent. of the total cost of operation. *Electrical World*, April 14, 1888.
- Electric Lighting** *Tower System*. Describes the system in practice at Detroit. Gives detailed drawing of the 150-foot towers, with dimensions. *Eng. and Build. Rec.*, Dec. 24, 1887.
- *Underground Wires of*. By W. W. Leggett, before the National Electric Light Association. Discusses the difficulties of putting the arc light wires underground. *Tel. Jour. and Elec. Rev.*, April 6, 1888.
- *of Passenger Trains*. Paper read before the American Institute of Electrical Engineers at its June meeting in New York, by G. W. Blodgett, Electrician of the Boston & Albany Railroad. Describes various methods, especially that in use on the B. & A. Railroad, employing storage batteries. *The Railroad and Engineering Journal*, Oct., 1887.
- *Validity of the Incandescent Patent*. Gives text of the decision of the High Court of Justice, England, in the matter of the Edison & Swan United Electric Light Co. vs. Holland and others. *Eng. and Build. Rec.*, Aug. 4, 1888.
- *Installation Breakdowns*. By R. F. Jones, before the old Students' Association, Finsbury Technical School. Gives a classification of breakdowns in electric plants; then gives actual cases, with their symptoms, causes and cures. *Tel. Jour. & Elec. Rev.*, June 22, 1888.
- *Installation*, "Kaiser Gallerie," Berlin. Gives description of the plant at the

- King's Gallery, Berlin, with a two-paged plate showing plan and section of engine room. *Engineer*, Sept. 21, 1888.
- Electric Lights for the New Cruisers.** Paper read before the National Electric Light Association by Lieut. J. B. Murdock, U. S. N., presenting in a general way the views of the Bureau of Ordnance of the Navy Department on the peculiar conditions to be met in the lighting of ships, and the best methods of meeting them. *The Railroad and Engineering Journal*, Oct., 1887.
- Electric Meter, Thomson's.** An electric current meter for continuous or alternating currents, invented by Prof. Elihu Thomson. The vaporization of a volatile liquid by the heat of the current is employed to effect a reciprocating motion, which is registered by a train. *Electrical World*, April 28, 1888.
- , *Meter.* A practical current meter, the invention of Prof. George Forbes, described by him before the American Institute of Electrical Engineers, Oct. 11, 1887. Illustrated. With interesting discussion. The meter is very simple, and works on the principle of a smoke jack by a current of heated air rising from a coil. *The Electrician and Electrical Engineer*, Nov., 1887.
- Electric Motors, Designing.** By T. Waku. Discusses the best practical method of proportioning and the proper winding of motors, and gives practical experience in the construction of special motors. *Mech. World*, Feb. 18, 1888; *T. J. and Elec. Rev.*, Feb. 24, 1888.
- , *An exposition of the principles with especial reference to the Sprague system.* Presented to the U. S. Naval Institute, May 16, 1887, by F. J. Sprague. *Proceedings of the U. S. Naval Institute*, Vol. XIII., No. 3.
- , *Charges for Services.* A paper presented to the Electric Light Convention, showing that there is a general average controlling the use of machinery which is safe for power companies to follow in making charges for electric motors. *Sci. Am. Supple.*, Sept. 22, 1888.
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- , *for Alternating Currents.* Paper read before the American Institute of Electrical Engineers, May 16, 1888. By Nikola Tesla. A new principle in electric motors, apparently the most practical scheme yet proposed for alternating current work; also some remarks on transformers. *Electrical World*, June 2, 1888; *Electrical Engineer*, June, 1888; *Tel. Jour. & Elec. Review*, June 15 and 22, 1888.
- , *How to make a Simple.* By G. M. Hopkins. Gives full instructions by which a motor can be made with ordinary tools. Illustrated. *Sci. Am. Supple.*, April 14, 1888; *Tel. Jour. & Elec. Rev.*, April 13, 1888.
- , See *Dynamos.*
- Electric Road in Hamburg.** By J. L. Huber, before the Institution of Civil Engineers. Gives details of the trial trips made on the Hamburg electric road with the Julien system. *Proc. Inst. C. E.*, Vol. XCII., pp. 301-311.
- Electric Railroads.** By J. T. Sprague, before the American Institute of Electrical Engineers. A valuable and exhaustive paper, covering the whole field of electric railroads; also contains a description of the Richmond line, with detailed account of daily working expenses. Abstracted *T. J. and Elec. Rev.*, August 3, 1888. *R. R. Gazette*, Nov. 2, 1888.
- Electric Railroad, St. Paul.** Gives a brief sketch, with drawing, of an electric railroad in St. Paul. The cars are suspended from an overhead rail. *Engin. and Build. Rec.*, Aug. 4, 1888.
- , *Street Cars, Methods of Gearing for.* Paper read before the American Institute of Electrical Engineers, Sept. 20, 1887, by A. Reckenzaun, C. E. Compares different methods of gearing in use, and advocates the use of worm-gearing. *The Electrical World*, Oct. 1, 1887.
- Electric Wave and Phase Indicator,** for alternating and undulatory currents. A diaphragm is made to move a light mirror in harmony with the current vibrations, and the form of the waves is indicated by the movement of a spot of light. In this way photographs of the wave forms may be made. Elihu Thomson in *The Electrical World*, Jan. 28, 1888.
- Electrical Measuring Instruments.** *Sir Wm. Thomson's New.* A new system of standard electrical measuring instruments in which the electrical force is balanced by gravity. *Electrical World*, Feb. 25, 1888.
- Electrical Resistance, Compensated Standards of.** Paper read before the Ameri-

- can Institute of Electrical Engineers, May 16, 1888. By Edward L. Nichols. Describes a method of making a standard of resistance unaffected by temperature, by combining copper and carbon. *Electrical Engineer*, June, 1888. *Electrical World*, June 9, 1888.
- Electrical Subway, New York.** Gives a good history of the Board of Electrical Control of New York City and its work. *Eng. News*, April 21, *et seq.*, 1888.
- Electrical Stresses.** By A. W. Rucker and C. V. Bays, before the Society of Telegraph Engineers and Electricians. An interesting paper on some phases of static electricity. Illustrated. *Sci. Am. Suppl.*, May 19.
- Electric Traction** By G. de Coetlogon. An abstract of a paper in *Le Genie Civil*. Describes the methods of transmission, motive force, existing electric traction enterprises, and traction by accumulators. *Engin. News*, Aug. 18, 1888.
- Electrical Units.** A paper by Prof. F. E. Nipher, explaining the origin and meaning of the terms volt, ohm and ampere. *Jour. Assoc. Engin. Soc.*, Vol. VII., pp. 83-89 (March, 1888); *Tel. Jour. & Elec. Rev.*, April 27, 1888.
- Electric Welding.** By C. J. H. Woodbury, before the Scranton meeting of the American Society of Mechanical Engineers. Reviews the principles upon which electric welding is based, describes the apparatus used and then considers its practical applications. *Amer. Eng.*, Oct. 17, 1888; *R. R. Gaz.*, Nov. 2, 1888.
- Electrical Welding.** Abstract of a paper by Professor Ruhlman, giving an account of the process and the description of the advantages which are claimed as resulting from it. Illustrated. *Engineering*, Jan. 27, 1888; *Sci. Am. Supple.*, March 3, 1888; *Eng. & Build. Rec.*, March 31, 1888.
- , *Practical Application of.* By O. K. Stewart, before the Boston Electric Club. Discusses the present aspect of the question and tells what is now being done in practical work. *Sci. Am. Supple.*, July 21, 1888.
- , *by Means of the Arc.* An illustrated description of the method and apparatus. *Electrical World*, Feb. 25, 1888.
- Electricity Applied to Engineering.** By Wm. Geipel before the Institution of Mechanical Engineers. An exhaustive view of the practical application of electricity to industrial uses. Treats of the electrical transmission and distribution of power, of locomotion, lighting and metallurgy. *Engineering*, Oct. 24; *Sci. Am. Supple.*, March 10, 1888.
- *as a Motive Power.* By Wm. Wharton, before the Philadelphia Street Railway Convention. Gives a full review of electricity as applied to the propulsion of street cars, with figures of expense and practical details. *Sci. Am. Suppl.*, Dec. 3, 1887.
- Electricity. Construction of Plant.** By Elihu Thomson, before the American National Electric Light Association. Discusses the insulation and installation of wires and the construction of plants. *Tel. Jour. & Elec. Rev.*, March 23, 1888.
- *Current to Produce Adhesion.* By E. E. Ries. Gives results of experimental examination of the electric current as a means of increasing the tractive adhesion of railway motors and rolling contacts. *Sci. Am. Suppl.*, Dec. 10, 1887.
- , *Distribution of.* By J. K. D. Mackenzie before the Society of Telegraph Engineers and Electricians. Discusses the use of secondary generators as transformers for the distribution of electricity. Gives points on the practical working of the system. *Elec. Rev.*, Feb. 17, *et seq.*, 1888.
- *in Mills, Various Uses for.* By C. J. H. Woodbury. Mentions briefly various applications of electricity to purposes other than lighting. *The Electrician and Electrical Engineer*, November and December, 1887.
- , *Influence Machines.* By James Wimshurst before the London Royal Institution, giving a full account of the recent forms of generators of static electricity. Illustrated. *Tel. Jour. & Elec. Rev.*, May 26, 1888.
- , *Its Production Direct from Fuel by Edison's Pyromagnetic Dynamo.* Paper read before the American Association for the Advancement of Science, New York. By Thomas A. Edison. *The Railroad and Engineering Journal*, October, 1887.
- , *Kirchoff's Laws and their application.* By E. C. Rimington. Gives a good description of the application of Kirchoff's laws to the finding of currents in a network of conductors. Illustrated with many diagrams. *Tel. Jour. & Elec. Rev.*, March 2, *et seq.*, 1888.
- , *Measurement of Supply.* By W. Lowrie before the Bath meeting of the

British Association. Describes the system of measurement of house-to-house supply of electricity in use in Eastborne, Eng. *Tel. J. and Elec. Review*, Sept. 21, 1888.

Electricity, Modern Views of. Extracts from lectures by Dr. Oliver Lodge in London and Birmingham. Not published before. *Engineer*, Nov. 4, 1887.

—, *On Flashing Carbon Filaments at Different Temperatures.* By L. S. Powell. Gives details and results of experiments made to obtain a clearer insight of what really goes on by employing different temperatures in flashing. *Tel. Jour. and Elec. Rev.*, May 4, *et seq.*, 1888.

—, *Projection of Lines of Force.* By J. W. Moore. Gives an illustrated description of the use of the lantern in obtaining direct optical projections of electrodynamic lines of force and other phenomena. *Sci. Am. Supple.*, April 21 and 28, 1888.

Electricity. *Report of Board of Control, N. Y.* Gives an abstract of the report of the Board of Electrical Control, addressed to the Governor and Legislature of New York State. Illustrated. *Eng. and Build. Rec.*, Jan. 14, 1888.

—, See Voltmeters.

—, *Standardizing Electrical Instruments.* By A. W. Meikle, before the Physical Society of Glasgow University. Gives a description of an application of the electrolysis of copper sulphates which has been employed for standardizing-purposes in the Physical Laboratory of Glasgow University for the last two years. *Tel. Jour. and Elec. Rev.*, March 23, *et seq.*, 1888.

—, *The Volt, the Ohm and the Ampère.* A mathematical exposition of the method employed in fixing the values of these units. Read before the Engineers' Club of St. Louis, by Prof. F. E. Nipher, of Washington University. *Journal of the Association of Engineering Societies*, March, 1888. *Tel. Jour. and Elec. Rev.*, April 27, 1888.

—, *Transformers vs. Accumulators.* By R. E. Crompton, before the Society of Telegraph Engineers and Electricians. A valuable paper, presenting facts and figures relating to the distribution of electricity by accumulators as transformer *vs.* transformers. Discussion. *Tel. Rev. and Elec. Rev.*, April 20, *et seq.*

Elevated Railroad. Gives detail of iron work on the Inter-state Rapid Transit Railroad, K. C. *Eng. News*, May 19, 1888.

—, *Berlin.* Gives a complete account of the structure, with details of construction, traffic, etc. Illustrated. *Engin. and Build. Record*, Feb. 4, *et seq.*, 1888.

Elevator, Most Economic. By E. E. Magovern. Gives results of tests made on the elevators supplied by the New York Steam Company. *Steevn's Indicator*, January, 1887; *San. Engr.*, Dec. 3, 1887.

Embankment, Rapid Construction. By J. A. Smith. Describes the method adopted for filling Hall street, St. Louis, in a short space of time. *Jour. Assoc. Engin. Soc.*, Vol. VII., pp. 103-106 (March, 1888). *Engin. & Build. Rec.*, March 21, 1888. *R. R. Gazette*, June 1, 1888. *Engin. News*, Aug. 18, 1888.

—, *Stability of Swamp.* By Samuel McElroy. Gives experience in dealing with embankments over swampy ground. *R. R. Gazette*, Aug. 31, 1888.

Engine, Compound. Illustrated description of an engine exhibited at the Rouen Exhibition and now in the Loubardemont flour mills. *Engineer*, July 15, 1887.

—, *Compound, at Dublin.* A short description, with a two-page plate showing plan, elevation, cross-section and valve gear of a compound condensing engine fitted with Collman's valve gear. Cylinders are cast steel, jacketed, 14 and 20 inches in diameter, 28 inches stroke; speed, 87 revolutions; pressure, 150 lbs.; horse-power, 150. *Engineering*, Feb. 3, 1888.

—, *Compound Corliss.* Gives a brief description with two-page plate and other engravings of a compound Corliss engine. Cylinders 40 × 70 in., stroke 72 in., 2,500 indicated horse-power. *Engineering*, April 16, 1888.

—, *Compound Horizontal.* Gives an illustrated description of a compound horizontal 2,000 indicated horse-power engine. Cylinders 38 and 66 in. in diameter, 6 feet stroke, pressure 95 lbs., piston speed 600 feet per minute. *Engineering*, Jan. 20, 1888; *Sci. Am. Supple.*, Feb. 25, 1888.

—, *Compound Pumping.* A two-page plate showing the engines and pumps of the Southwark and Vauxhall Water Company and other engravings, giving engine details. Engines are inverted double-cylinder compound direct-acting rotative. *Engineer*, July 22, *etc.*, 1887.

- Engine, Compound, Use of, for Manufacturing Purposes.** By Chas. S. Main, before the Scranton meeting of the American Society of Mechanical Engineers. Discusses the use of the compound engine for manufacturing purposes, the relative areas of cylinders and the regulation of pressure in the receiver. *Amer. Eng.*, Oct. 24, 1888; abstracted *R. R. Gazette*, Oct. 19, 1888.
- , **Compound Tandem.** Brief description, with two-page plate showing plan, elevation and sections of exhaust valves of a tandem compound horizontal engine, constructed at Rouen. *Engineering*, Nov. 11, *et seq.*, 1887.
- , **Compound Vertical.** Detail drawings, fully dimensioned, of all the parts of the engines for the Indian State Railway. *Engineer*, Sept. 2, *etc.*, 1887.
- , **Davey's Differential Pumping.** Brief description, with two-page plate and other engraving, showing plan, elevation and cross-sections of Davey's differential pumping engine for the Weston Water-Works. *Engineer*, Jan. 13, 1887.
- , **Gas, Atkinson.** Brief description, with indicator diagram, of the Atkinson gas engine, which gave a brake horse-power, for 20.5 cubic feet of gas. Illustrated. *Engineer*, Dec. 30, 1887.
- , **Gas, Beck's.** A report of an exhaustive series of experiments made by Prof. A. B. W. Kennedy on Beck's gas engine. Illustrated. *Engineer*, May 4, 1888. Abstracted *Engin. News*, June 9, 1888.
- , **Gas, Griffin.** Gives details of experiments with a Griffin gas engine. Showed a consumption of 18.86 cubic feet per hour per horse-power. *Engineering*, April 13, 1888; *Engineer*, May 25, *et seq.*, 1888.
- , **Gas, Sturgeon.** Brief description, with drawing, of the cylinders of the Sturgeon gas engine. *Engineer*, June 15, 1888.
- , **Hot Air, Benier's.** Description of the above engine, with plan, sectional elevations and sections. *Engineer*, Nov. 4, 1887; *Sci. Am. Suppl.*, Dec. 10, 1887. *Polytechnische Journal*, Vol. CCLXVII., 1888, p. 193.; *Abst. Proc. Inst. C. E.*, Vol. XCII., pp. 483-9.
- , **Heat in the Steam.** Gives translation of the explanation of Prof. Dwelshauveras-Déry's diagrams of exchange of heat between metal and steam in a steam engine. Illustrated. *Engineering*, July 27, 1888.
- , **Hargreaves Thermo-Motor.** Gives a description, with a sectional elevation, of Hargreaves thermo-motor, which, at 100 revolutions per minute, indicated 40 horse-power. It consumes 20½ lbs. of coal tar per hour. The highest available efficiency is 73 per cent. *Engineer*, Jan. 27, 1888; *Power and Steam*, March, 1888.
- , **Horizontal Corliss.** Gives two-page plate and short description of an 18 by 43 Corliss engine. *Engineering*, April 20, 1888.
- , **Petroleum Spirit.** Gives a series of interesting diagrams from a petroleum spirit engine. *Engineer*, June 15, 1888.
- , **Pumping.** Illustrated description of a new form of pumping engine for Champaign, Ill. It is a vertical compound duplex direct double-acting steam pump, with outside flanges. *Eng. News*, Nov. 26.
- , **Pumping Test of Philadelphia Water-Works.** A report by J. L. Ogden, J. E. Codman and F. T. Hally on the duty and capacity of a 20,000,000 gallons Gaskill engine at the Spring Garden pumping station, Philadelphia. Gives the method of conducting test, with calculated and observed data. The engine gave a duty of 122,522,276 foot-pounds per 100 pounds of coal. *Eng. News*, Feb. 18, 1888.
- , **Pumping, Umaria Colliery.** Gives abstract from the specification for the construction of a colliery plant in India. Illustrated. *Engineer*, Aug. 19, 1887.
- , **Riggs High Speed.** Describes a new and ingenious type of four-cylinder revolving steam engine, capable of attaining 2,000 revolutions per minute. Illustrated. *Mech. World*, Feb. 18, 1888; *Sci. Am. Suppl.*, March 10, 1888.
- , **Rota.** Gives brief description of a new type of high-speed engine. *Ill. Eng.*, July 20, 1888.
- , **Steam, Applied to Bicycle and Tricycle.** A description of a small, light steam engine and boiler, invented by L. D. Copeland. *Am. Machinist*, March 3, 1888.
- , **Triple Compound.** Perspective view of a set of triple expansion engines and specifications to which they were built. *Engineer*, Aug. 26, 1887.
- , **Triple Expansion.** Gives view and brief description of the triple expansion engines of the steamer "City of New York." The cylinders are 45, 71 and 113 inches; stroke, 5 feet; indicated horse-power, 20,000 at 150 lbs. pressure. *Engineering*, Aug. 3, 1888.

- Engine, Triple Expansion.** Sectional elevation and perspective views of the triple expansion engines of the Italian cruiser "Dogali." *Engineer*, Aug. 5, 1887.
- , **Triple Expansion Non-Condensing.** Gives a description, with dimensions, of a triple expansion non-condensing engine that gives an indicated horse-power per hour for 1.45 lbs. of coal. *R. R. Gaz.*, Aug. 3, 1888; *Eng. News*, Aug. 11, 1888.
- Engines, Copper Steam Pipes for.** By W. Parker, before the Institution of Naval Architects. Gives a summary of investigations and results of experiments made to ascertain the behavior of different kinds of commercial copper under various treatments and temperatures. *Engineering*, August 3, 1888; *Am. Engr.*, Aug. 29, *et seq.*, 1888; *Sci. Am. Supple.*, Sept. 1, 1888.
- , **Compound and Non-Condensing Steam Jackets, etc.** By Chas. E. Emery. Presents tabular statement showing the results of experiments made in 1874 on a number of steamers to ascertain the best means of securing economy of fuel. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 367-394.
- , **Economy Trials of the Non-Condensing.** By P. W. Williams, before the Institution of Civil Engineers. Gives details of a series of economy trials made on a triple expansion engine used as a simple, compound and triple engine. *Proc. Inst. C. E.*, Vol. XCIII., pp. 128-243; *R. R. Gazette*, April 6, 1888; *Mechanical World*, March 24, 1888; *Engineer*, April 6, 1888; *Sci. Am. Supple.*, May 26, 1888.
- , **Efficiency of Plant.** By Prof. De Volsen Wood. A review of the recent steam engine efficiency. *Sci. Am. Supple.*, Sept. 1, 1888.
- , **Friction of Non-Condensing.** Paper read at a meeting of the American Society of Mechanical Engineers, New York, November, 1886; by Prof. R. H. Thurston, of Cornell University. Describes experiments showing that the friction of a non-condensing engine is practically the same for all loads. *Trans. Am. Soc. of Mechanical Engineers*, Vol. VIII., 1887; *Am. Engr.*, Dec. 14, *et seq.*, 1887. A paper before the Philadelphia meeting in *Trans. Am. Soc. of Mech. Engrs.*, Vol. IX., 1888, on the same subject. Abstracted *Engin. News*, May 26, 1888.
- , **Marine, First Century of the.** By Prof. H. Dyer, before the Institution of Naval Architects. Gives a brief résumé of the chief steps in the development of the steam engine and marine navigation. *Engineer*, Sept. 21 and 28, 1888.
- , **Marine, Development of.** A series of illustrated articles with the object of describing and illustrating the marine engines in the existing ships of the British Navy, and to trace the development of the engine from the type fitted in the oldest of them to that at present being fitted in the most modern. *Engineer*, March 23, *et seq.*, 1888.
- , **Mill.** By B. H. Thwaite. A lecture before the Textile Society of Yorkshire College, Leeds, giving retrospective history of the transition in the development of the steam engine. *Engineering*, July 13, *et seq.*, 1888.
- , **New Principle in Piston Packing.** By John E. Sweet, before the Philadelphia meeting of the American Society of Mechanical Engineers. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX., pp. 91-99.
- , **Proportioning of Cylinders.** By R. H. Thurston, before the American Society of Mechanical Engineers. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 360-368.
- , **Reciprocating, Dynamics of.** By Prof. M. E. Cooley. A very careful and thorough study of the forces acting on the crank pin, etc., with diagrams. *The Technic*, Univ. of Michigan, 1888.
- , **Triple Expansion.** By Wm. M. Henderson. A paper before the Franklin Institute describing Henderson's improved triple expansion engines. Claims to have the fewest possible number of parts. *Sci. Am. Supple.*, Nov. 26, 1887.
- , **Triple Expansion for Lake Service.** By W. Miller. Gives his experience with triple expansion engines, and describes the different designs brought out. *Jour. Assoc. Engin. Soc.*, Vol. VII., pp. 75-83 (March, 1888).
- , **Triple Expansion of S. S. "Courier."** Brief description, with two-page plate, giving two perspective views of the triple expansion engines of the steamship "Courier." *Engineering*, Jan. 6, 1888.
- , **Triple Expansion of H. M. S. "Orlando" and "Undaunted."** Two two-page plates, showing vertical and horizontal sections through engine and boiler-rooms, two cross sections, and three perspective views of the triple expansion engines of the steamers "Orlando" and "Undaunted." *Engineering*, Nov. 4 and 23, 1887.

- Engines, Volatile Vapor.** By A. F. Yarrow, before the Institution of Naval Architects. Discusses the possible advantage of using highly volatile liquids in lieu of water for the purposes of propulsion. Describes a launch propelled by a volatile hydrocarbon. *Engineering*, April 9, 1888.
- Engine Trial, Newcastle.** Gives full particulars of the engines and boilers, with results of trial, tested by the Royal Agricultural Society at Newcastle, England. *Engineering*, Nov. 18, *et seq.*, 1887; *Engineer*, Nov. 19, *et seq.*, 1888.
- Engineer His Commission and His Achievements.** President C. H. Babcock's address before the American Society of Mechanical Engineers. *Trans. Am. Soc. of Mech. Engrs.*, Vol. IX. (1888), pp. 23-37.
- Engineering, Agricultural, in India.** A series of articles on irrigation, with the side issues, geological, social and financial, which must be considered in an extensive scheme. *Engineering*, April 6, *et seq.*, 1888.
- , *Review of for 1887.* A long editorial in *Engineer* for Jan. 6, 1888, gives a good review of the engineering progress and practice for the year of 1887.
- , *Estimates, Costs, Accounts, etc.* A series for young engineers showing the methods of making estimates, etc., with a discussion of the underlying principles. *Mech. World*, Jan. 6, 1887.
- Engineering Structures, Destructive Agencies in.** A series of articles discussing the agencies tending to destroy engineering structures and their remedies. *Am. Eng.*, Aug. 15, 1888.
- Estuaries, Tidal and the Bar of Mersey.** By W. H. Wheeler. Gives a general discussion of two papers read before the British Association. *Engineer*, Nov. 11, 1887.
- Excavators, Steam.** By W. L. Clements before the American Society of Mechanical Engineers. Describes the general construction of steam excavators, and then gives detail of a special machine. Abstracted, *R. R. Gazette*, May 11, 1888; also *Eng. News*, May 26 *et seq.*, 1888, and supplemented by information from other sources.
- Explosives and their Composition.** By W. C. Foster. Gives a list of the explosives most commonly used, with the composition, and references to publications in which notes may be found. *Eng. News*, June 30 *et seq.*, 1888.
- , *Composition of High.* Gives interesting list of the composition of high explosives. *Le Genie Civil*, Oct. 22, 1887; *San Engr.*, Nov. 26, 1887.
- , *Roburite.* Gives results of experiments in mining coal with roburite. *Engineer*, Oct. 28, 1887; *Sci. Am. Suppl.*, Nov. 19, 1887.
- , *A New.* Gives some of the characteristics and properties of a new explosive called Emmensite, said to better than dynamite. *Am. Engr.*, Nov. 23, 1887; *Sci. Am. Sup.*, Jan. 7, 1888.
- Extension, Elastic.** By R. H. Graham. Gives a mathematical treatment of the subject of elasticity. Considers it a form of motion and subject to the laws of velocity and acceleration. *Engineer*, Aug. 19, 1887.
- Falls of St. Anthony, Preservation of the Apron at the.** By A. Johnson, before the Engineers' Society of St. Paul. Gives description of the Falls of St. Anthony, the main work constructed for their preservation, and describes in detail the construction of a crib to protect the apron of the fall. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 271-279.
- Filter, Warren Water.** Description of the Warren water filter, with plan and sections. *Eng. News*, Nov. 19, 1887.
- Filtration, Gerson's System.** Describes a process in which water is passed through sponges and pumice stone filled with insoluble tannate of iron. Gives analysis of water before and after passing the filter. *Engineering*, Nov. 18, 1887.
- , *Practical Results of Mechanical.* By W. S. Richards. A paper before the American Water-Works' Association, giving experience with Hyatt filters at the Atlanta Water-Works. *Proc. Amer. Water-Works Assoc.*, 1883, pp. 143-152. Abstracted *Engin. and Build. Rec.*, May, 1888.
- , See Water Supply.
- Firearms, Development of Automatic.** Gives a two-page plate and short description of the details of the Maxim gun. *Engineering*, Jan. 27, 1888.
- Fire Grates, Donncley for Boilers.** Gives plan, elevation and section of the Donncley fire grate, and the results of experiments with different kinds of coal. *Railroad Gaz.*, Jan. 6, 1888.
- Fires, Prevention and Extinction of.** By A. Chatterton, before the students of the

- Institution of Civil Engineers. Discusses the causes of fires, fire-proof material, fire-proof construction, internal and external appliances for extinguishing fires. *Proc. Inst. C. E.*, Vol. XCIII., pp. 437-461.
- Flexure, Resistance of Beams to.** By J. G. Barnard. An abstract from a paper on the resistance of materials, by M. Decamille, with comments. *Trans. Am. Soc. C. E.*, Vol. III., pp. 123-128.
- Flooring, Steel.** Gives description, with illustrations showing its application of Lindsay steel flooring. *Engineer*, Oct. 7, 1887; *Engr. News*, Nov. 26, 1887.
- Floor-Beam, Test of a.** By A. P. Boller, before the American Society of Civil Engineers. Gives details of the testing of a full sized wrought-iron double track floor beam. Three plates. Discussion. *Trans. Am. Soc. C. E.*, Vol. XVIII., May, 1888, pp. 119-130; *Engineer*, April 27, 1888; *Sci. Amer. Sup.*, June 2, 1888.
- Flow of Air, in Sewers.** See Sewers.
- Flow of the West Branch of the Croton River.** By J. J. R. Croes. Gives details of the rainfall and gauging of the west branch of the Croton River from 1866-72. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., pp. 76-86.
- Flow of Water, New Formula for, in Pipes and Open Channels.** By E. C. Thrupp. Gives a modification of Hogan's formula, based on experiments applicable to pipes and open channels. Compares experiments with results obtained by calculation. *Engineer*, Dec. 16, 1887. Abstract in *Sci. Am. Supple.*, Feb. 11, 1888.
- , *New Formula for.* By E. C. Thrupp, before the Society of Engineers. Gives details of experiments with pipes and open channels, and shows method of deriving his new formula for the flow of water. *Trans. Soc. Engrs.*, 1888, pp. 224-264.
- Flow of Water in Mains, as Determined by Pressure Gauges.** A paper by George A. Ellis, showing how the flow in pipes may be estimated from the loss of head. *Jour. New Eng. W. Works Assoc.*, Sept., 1886.
- Flood Gates, Automatic.** Gives brief description, with cuts, of the Czvetkovics automatic flood gate. *Engineering*, July 13, 1888.
- Forests, Their Influence on Rainfall.** A paper by Prof. Geo. F. Swain, giving an able and rational discussion of the subject, and including a synopsis of the known facts relating thereto. *Jour. New Eng. W. Works Assoc.*, Vol. I., No. 3.
- Forced Draught, Closed Stakehold System.** By Thos. Soper, before the Institution of Naval Architects. Gives a discussion on the use of forced draught under boiler in the closed stakehold system. Contains the experience gained with vessels in the British Navy. *Engineer*, April 6, 1888; *Engineering*, April 6, 1888.
- , By J. R. Fothergill, before the Institution of Naval Architects. Gives the results of trials made with forced draught on the steamers "Marmora," "Dania" and "Elna." The summary shows a slight reduction in speed, with a saving of from 20 to 30 per cent. in fuel. *Engineer*, April 6, 1888; *Engineering*, April 6, 1888.
- Friction in Tooth Gearing.** By G. Lanza, before the American Society of Mechanical Engineers. Gives a mathematical investigation of friction in the involute and epicycloidal forms of gearing. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX., pp. 185-228.
- , *of Collar Bearing.* Gives the third report of the research committee "On Friction" of the Institution of Mechanical Engineers. Report gives results of experiments on the friction of collar bearings, with description of apparatus. *Engineer*, May 4, 1888.
- , *of Piston Packing Rings.* By Prof. J. E. Denton, before the Scranton meeting of the American Society of Mechanical Engineers. Gives results of a series of experiments made with a special instrument for measuring the friction of piston packing rings in steam cylinders. *R. R. Gazette*, Oct. 19, 1888; *Amer. Engr.*, Oct. 24, 1888.
- , *of Metal Coils.* By Prof. Hele Shaw and Edward Shaw, before the Bath Meeting of the British Association. *Engineer*, Sept. 28, 1888.
- , *Journal.* See Railroads.
- , *Recent Researches in.* By John Hoodman, before the Students of the Institution of Civil Engineers. Gives a comparison of the results obtained by various authorities and examines the phenomena from a theoretic point of view. *Engr. News*, March 31 et seq., 1888.

- Friction Clutches.** By Geo. Adams. A practical paper on the construction of friction clutches. Illustrated. *Engineer*, Sept. 1, 1888.
- Frictional Gearing on a Dredge.** By J. G. Griffith, before the Institution of Mechanical Engineers. Gives a description of the frictional gearing used on a double steam dredge in the port of Dublin. Illustrated. *Engineer*, Aug. 24, 1888.
- Frogs and Switches.** Discussion, at the January meeting of the New England Railroad Club, of frogs and safety switches. *R. R. Gazette*, Jan. 20, 1888. *Master Mechanic*, Feb., 1888.
- Foundation, Method Pursued in Replacing a Stone Pier on a Pile.** By J. A. Monroe. Gives description of the method employed to replace on the pile foundation a grillage with two courses of masonry, which had broken loose and settled 14 inches out of place. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., p. 59.
- Foundations for the Brooklyn Anchorage of the East River Bridge.** By T. Collingwood. Gives details of method of construction adopted. *Trans. Am. Soc. C. E.*, Vol. III., pp. 142-146.
- , **Pile.** By Julian Griggs. Describes the common methods of managing pile foundations for bridge masonry and trestles. *Report Ohio Soc. Surv. and Engrs.*, 1888, pp. 209-216.
- , **Replacing, under Elevator at Providence, R. I.** By A. McL. Hawks. Gives details of the method employed to put a new foundation under one side of the Columbia Elevator at Providence, R. I. *Engin. News*, Feb. 25, 1888.
- , **Supporting Power of Soils.** By Randall Hunt. Treats of the supporting power of soils as deduced from personal observation and the recorded examples *Jour. Assoc. Eng. Soc.*, June, 1888, Vol. VII., pp. 189-196; *Eng. News*, June 16, 1888; *Sci. Am. Supple.*, June 30, 1888; *Engin. and Build. Rec.*, June 23, 1888.
- Foundry Work, Estimating Cost of.** By G. L. Fowler, before the American Society of Mechanical Engineers. Gives outlines of a plan used by the writer to find the cost of castings. *Am. Eng.*, May 9, 1888.
- Fuel, and Combustion.** By R. H. Buel. Gives a general synopsis of the most important principles and data from various sources. *R. R. Gazette*, July 13 et seq., 1888.
- , **Liquid.** Details of an interesting series of experiments on liquid fuel made by Mr. B. H. Thwaite. *Engineer*, Dec. 9, 1887.
- , **Liquid.** See Oil Burners.
- , **Petroleum Oil as.** Gives a report of the tests made at the Salem pumping station, to test the value of petroleum as fuel, when converted into and used as gaseous vapor. The oil was found more economical than coal. *Am. Manuf.*, April 6, 1888.
- , **Petroleum Oil vs. Coal.** By C. E. Ashcroft. Considers theoretically and practically the use of petroleum oil as fuel in place of coal. Gives valuable comparisons of test trips on the Russian railroads. *Am. Manuf.*, May 25, 1888.
- Fuel Gas.** By J. M. Cutchlow, before the Ohio Gas Association. *Am. Manufacturer*, March 30, 1888.
- , **and Incandescent Gas Lighting.** By Chas. M. Lungren. Gives comparison of the economy of the different methods of illumination, with figures of cost. *Sci. Am. Supple.*, March 3, 1888.
- , See Gas.
- Furnace, Blast, Charges.** By R. H. Richards and R. W. Lodge. Before the Duluth meeting of the American Institute of Mining Engineers. Gives experiments illustrating the descent of charges in an iron blast furnace. *Engineering*, Jan. 20, 1888.
- Furnaces, Construction of, for Liquid Fuel.** A valuable series of papers by Herr Busley, in *Wochenschrift des Vereines Deutscher*, reviewing the use of liquid fuels. The methods employed are classified and a large number of various appliances of these methods are illustrated and described. Translated in *Engineer*, Feb. 10 et seq., 1888; *Power-Steam*, June et seq., 1888.
- , **Efficiency of Burning Wet Fuel.** By R. H. Thurston. Gives results of experimental investigation made upon two distinct varieties of furnaces burning spent tan-bark wet from the leaches. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 290-318.
- , **Safe Working Pressures for Cylindrical.** By M. Langridge. Discusses the different formulæ relating to the safe working pressure on cylindrical furnaces

- and flues, showing their discrepancies, and proposed a modified form of Fairbairn's formula. *Engineer*, Sept. 21, 1888.
- Gas.** *Loomis Fuel Gas Plant.* Gives brief description of the Loomis fuel gas plant at Tacony, Pa., with account of the Loomis system of production. *Amer. Manuf.*, Oct. 5, 1888.
- , *Natural, Industry at Pittsburgh, Pa.* Gives details of the method of connecting wells to main, regulating pressure, distribution of gas, etc. *Sci. Am. Suppl.*, Jan. 7, 1888.
- , *Substitute for Natural.* Gives details of the Johnson process of manufacturing a fuel gas from crude oil, and the results obtained from burning the gas. *Am. Manuf.*, July 20, 1888.
- , *Water.* An article reprinted from *Industries*, giving analysis of the various forms of water gas. Describes the plant most generally used, chemical reactions, etc. *Am. Manuf.*, Feb. 10, 1888.
- , *Water.* By G. H. Christian, Jr., before the Ohio Gas Light Association. Gives the results of experiments to substitute Lima crude oil for naphtha in the manufacture of water gas. *Am. Manuf.*, April 23, 1888.
- Gas.** *Water for Metallurgical Purposes.* By A. M. Wilson before the Iron and Steel Institute. Gives analyses of the various forms of water-gas; describes the plant most generally used for its manufacture, chemical reactions, etc. *Sci. Am. Supple.*, July 14, 1888.
- Gaseous Fuel.** By J. E. Dawson before the British Association for the advancement of Sciences. *Am. Manufac.*, Oct. 26, 1888.
- Gas Engines.** See Engines.
- Gas Holders Without Upper Guide Frames.** By T. Newbegg, before the Manchester District Institution of Gas Engineers. Describes a method of constructing gas-boilers with inclined guides at the base, constructed in such a manner as to do away with a large part of the upper frames. *Engineer*, Sept. 14, 1888.
- Gauges, Recording Pressure.** By Chas. A. Hague before the Minneapolis meeting of the American Water-Works Association. Discusses the uses and advantages of recording pressure gauges in water-works. *Proc. Seventh An. Meet. Am. Water-Works Assoc.*, pp. 24-31; *Am. Engr.*, Feb. 8 and 15, 1888.
- Geology.** By Archibald Geikie. A series of articles giving a full treatment of the subject of rock formation. *Sci. Am. Supple.*, Aug. 11 et seq., 1888.
- Garbage, Disposal of.** See Town Refuse.
- Gas.** *An Oil or Gas Well Rig.* A good description of the ordinary apparatus for drilling for petroleum or natural gas. *Age of Steel*, April 14, 1888.
- , *Compressed Oil Gas and its Applications.* By Arthur Ayres before the Institute of Civil Engineers. Discusses the application of compressed oil gas to light-houses, railroad cars, etc. Describes the Pintsch works at South Foreland. *Proc. Inst. C. E.*, Vol. XCIII., pp. 298-349; *Engineering*, April 13, 1888. Abstracted. *Sci. Am. Supple.*, May 19, 1888.
- , *Fuel.* By Walton Clark before the Western Gas Association. Compares the relative efficiencies of pure fuel gas and a mixture of coal, water and producer gas. *Am. Manuf. and Iron World*, June 22, 1888.
- Girders, Plate, Calculation of.** By A. Münster. Gives results of investigations as to the reliability of formulas in use for calculating the flange stresses in plate girders. Presents three new formulas. Gives table showing the moments of resistance as compared by different formulas. *Jour. Asso. Engin. Soc.*, February, 1888, pp. 55-58.
- Governor, Improved Form of Shaft.** By F. H. Ball before the American Society of Mechanical Engineers. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 300-323.
- Gradient, Ruling.** See Railroads.
- Gramophone.** *Etching the Human Voice.* A paper read before the Franklin Institute, May 16, 1888, by Emile Berliner. Sketches the history and present status of the invention. *Jour. Franklin Institute*, June, 1888.
- Guard Rails on Bridges.** See Bridges.
- Gun, Pneumatic.** See Ordnance.
- Hammers, Steam.** By C. Chomienne, Engineer. Translated from the French. The author has had many years experience in the management of extensive iron works. *Railroad and Engineering Journal*, June et seq., 1888.

- Harbor, Antwerp, New Works in.** By M. Strukel. Description, with illustrations, *Zietschr. d. Oester. Ing.-u. Arch. Vereins*, 1833, pp. 151-161.
- , **Karachi, India.** Gives memorandum of works in progress as proposed at an early date for the improvement of the harbor of Karachi, India, with map. *India Engineering*, Feb. 4 *et seq.*, 1833.
- , **New York, Improvement of Water Front.** By J. D. Van Buren, Jr. Gives characteristics of the harbor, physical feature of the island, and the systems adopted for improving the water front, etc. *Trans. Am. Soc. C. E.*, Vol. III., pp. 172-189.
- , **New York, Improvement of.** Gives a brief description of the centrifugal pumps in use on the excavator in New York harbor. *Sci. Am. Supp.*, Aug. 25, 1888.
- Harbors, Physical Phenomena of Entrances to.** An abstract from a lecture by Prof. L. M. Haupt before the American Philosophical Society. *Eng. News*, Feb. 25, 1888.
- Harbor and Waterways, National Bureau of.** Gives text of bill recently introduced into the Senate by Senator Collum, Ill., to establish a National Bureau of Harbor and Waterways. *Engin. and Build. Rec.*, Jan. 28, 1888.
- Heat, Fourier's Law of Diffusion.** By Sir. Wm. Thomson before the Bath meeting of the British Association. Gives five applications of Fourier's law of diffusion, illustrated by a diagram of curves with absolute numerical values. *T. J. and Elec. Review*, Sept. 23, 1888.
- , See Combustion.
- Heat and Power, Prall System of Distribution of.** By E. D. Meier before the Engineers' Club of St. Louis. Gives details of the Prall system of distributing heat and power from a central station as carried out in Boston. *Jour. Assoc. Engin. Soc.*, August, 1888, Vol. VII., pp. 305-313. *Sci. Am. Supple.*, Aug. 25, 1888.
- Heat and Steam, Notes on.** By R. H. Buel. A series of articles for practical men giving a collection of the most prominent data, with tables founded on the same, *Am. Engr.*, May 2 *et seq.*, 1888.
- Heating, Steam.** By Chas. E. Jones. Describes the plant in use at Washington University, and shows the work it is doing, also gives experience with underground pipes and smokeless furnaces. *Jour. Assoc. Engr. Soc.*, January, 1883, pp. 14-22; *Engin. and Build. Rec.*, Feb. 18, 1883. Abstract *Proc. Inst. C. E.*, Vol. XCII., pp. 431-2.
- , **Steam, in Cities.** By Chas. E. Emery. Gives a good exposition of the methods used by the New York Steam Company, with some valuable data. *Jour. Franklin Institute*, March, 1888. *Sci. Am. Supple.*, April 7, 1888.
- , See Car Heating.
- Heating and Ventilating Mass. Institute of Technology.** Gives the results of four years experience with the indirect method of steam heating and ventilating at the Massachusetts Institute of Technology. *Eng. News*, Feb. 25 *et seq.*, 1888.
- , **Warehouse Building.** By Henry J. Snell, before the Philadelphia meeting of the American Society of Mechanical Engineers. Describes a method practiced by the author for heating and ventilating an office and warehouse building in Philadelphia. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX., 1888, pp. 99-107.
- , **Warm Air.** By W. D. Snow. Discusses the uses of a forced current of warm air, and advocates the use of this method, with exhaust steam for shop warming. *Master Mechanic*, May, 1888.
- Heating and Ventilating Workshops.** By John Walker. Gives details of the system of hot air heating applied to some shops in Cleveland. Illustrated. *Jour. Assoc. Eng. Soc.*, Vol. VII., pp. 1-5 (January, 1888).
- Heating Plant, Boston.** Illustrated description of the plant of the Boston Heating Company. *Eng. News*, Nov. 12, 1887.
- , **Boston Heating Co.** By A. P. Abbott, before the Boston Society of Civil Engineers. Gives full description of the plant, the method of construction adopted in the streets and details of fixtures. *Eng. and Build. Rec.*, May 5, *et seq.*
- Heroult Process, Aluminum Alloys by the.** See Aluminum.
- Hydraulic Lift, Bombay Dock.** See Dock.
- Hydraulic Lift, Canal.** A two-page plate showing elevation, cross-section and details, with short description of the La Louvière hydraulic lift on the Canal du Centre, Belgium. Lift, 50.5 ft.; length, 142 ft.; weight, 1,100 tons. *Engineering*, Feb. 24, 1888.

Hydraulic Lift, Car. Brief illustrated description of the hydraulic car lift in the St. Lazare Station in Paris. *Railroad Gazette*, Nov. 18, 1887.

—, **Neuffossé Canal.** Brief description, with sections and elevation of the hydraulic lift at Fontinettes, on the Neuffossé Canal. *Engrs. and Build. Rec.*, June 23, 1888.

Hydraulic Power, Distribution of. By E. B. Ellington, before the Institution of Civil Engineers. Gives details of the distribution of hydraulic power in London. Has 27 miles of mains at a pressure of 700 lbs. per sq. in. *Engineering*, April 27, 1888; *Engineer*, May 11, 1888; *Mech. World*, May 12, 1888; *Amer. Eng.*, June 27, 1888.

Illumination, Economical from Waste Oils. By J. B. Hannay, before the Society of Arts. Describes the lucigen, an apparatus in which compressed air is used with waste oils, and its applications. *Jour. Soc. of Arts*, Dec. 2, 1887; *Sci. Am. Sup.*, Jan. 14, 1888. Abstracted in *Engineering*, Dec. 9, 1887.

Indicator. The Revolving Steam Engine Indicator. An article advocating the use of a steam engine indicator, with a continuously revolving drum, instead of the reciprocating style. *American Machinist*, Dec. 24, 1887.

Indicators. An interesting paper by Chas. E. Emery, before the American Society of Mechanical Engineers, showing the necessity of taking diagrams from the steam-chest at the same time as from the cylinder. Gives actual diagram. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 293-299; *Am. Engr.*, Dec. 7, 1887.

Injector, Mechanics of the. By J. B. Webb, before the Scranton Meeting of the American Society of Mechanical Engineers. *Amer. Engr.*, Oct. 17, 1888.

Injectors and Steam Pumps, Comparative Efficiency of. Finds the relative economy and difference in amount of fuel used with a boiler fed by a pump and by an injector. *Stevens Indicator*, April 20, 1888; *Am. Eng.*, April 18, 1888.

Inland Navigation. Fourteen papers on canals and inland navigation were presented before the recent Canal Conference held under the auspices of the British Society of Arts. They are mostly indexed under canals. See *Jour. Soc. of Arts*, May 25 *et seq.*, 1888.

—, Proceedings of the 1886 International Convention for Promoting Inland Navigation, held at Vienna, Austria. *Annales des P. and C.*, June, 1888.

—, in *Germany*. See Railways and Waterways.

—, in *Great Britain*. By E. J. Lloyd before the Society of Arts Canal Conference. Gives history of the development of inland navigation. *Jour. Soc. Arts*, May 25, 1888.

—, **Suggestions for its Improvement.** By M. B. Cotsworth before the Society of Arts Canal Conference. Discusses the present condition of inland navigation in the United Kingdom and gives suggestions for its improvements. *Jour. Soc. Arts*, May 25, 1888.

—, See Canals.

Iron, Influence of Aluminum on. See Aluminum.

—, **Mechanical Properties of Pure, as a standard base.** By President Adamson, before the Iron and Steel Institute. *Amer. Eng.*, July 6, 1888.

—, **Pig.** A lecture before the Franklin Institute, by A. E. Outerbridge, on the production of pig iron, including the relations between its physical properties and chemical constituents. *Sci. Am. Suppl.*, April 14, 1888.

—, **Protection against Corrosion.** By H. Haupt. Describes a new process for protecting iron from corrosion, which treats the heated metal in retorts with steam and hydrocarbon vapor. *Am. Manuf.*, July 6, 1888.

—, **Production of Pig, of a Definite Composition.** By H. Pilkington. Before the South Staffordshire Iron and Steel Institute. *Am. Manuf.*, Jan. 13, 1888.

—, **Relation between Physical Properties and Chemical Constituents of Pig Iron.** Abstract of a lecture before the Franklin Institute, by Alex. E. Outerbridge, Jr. *Journal Franklin Institute*, March, 1888.

—, **Rusting of.** By A. C. Brown, before the Edinburgh meeting of the Iron and Steel Institute. Explains the process involved in the rusting of iron. *Am. Eng.*, Sept. 26, 1888; *Master Mech.*, October, 1888; *Engineer*, Sept. 2, 1888.

—, **Silicon and Sulphur in.** By Thomas Turner before the Iron and Steel Institute. A record of interesting experiments on the effects of an addition of sulphur to cast iron rich in silicon. Concludes that silicon has the power of expelling sulphur from cast iron.

- Iron, Wrought.** Tabulated records in detail of results obtained from over 2,000 test pieces of wrought irons. *Rept. U. S. Board of Testing*, Vol. I., 1881, pp. 46-91.
- , *Wrought, Rerolling and Reheating.* Gives the results of experiments on the strength of wrought iron in bars and in chains; effects of different degrees of reduction in rolling, of reheating, rerolling and hammering; comparison of chemical causes with physical results, correct form of test pieces, and miscellaneous investigations into the physical properties of rolled wrought iron. *Report of U. S. Board of Testing, etc.*, Vol. I, 1881, pp. 1-210.
- , *Valuation of Pig.* By A. E. Tucker, before the Society of Chemical Industry. A valuable paper. *Engineering*, July 20, 1888.
- Iron and Steel, Analysis of.** By A. A. Blair. A paper giving the methods used for the analysis of metals for the Board of Testing Iron and Steel, etc. See *Report of Board on Testing, etc.*, 1881, Vol. I, pp. 248-266.
- , *Internal Stresses in.* By Gen. N. Kalakoutzky. A valuable series of articles giving results of original investigations. Discusses the determination of the influence of internal stresses, method of determining them, reduction, etc. *Engineer*, Dec. 9, 16, 23, 1887; *Sci. Am. Suppl.*, Feb. 18, 25, 1888.
- , *Tests of.* Over 700 specimens of iron and steel given in detail. Taken mostly from guns, sbt and shell. Watertown Arsenal Report for 1885. Ex. Doc., No. 36, 49th Cong., 1st Session.
- Ironwork Construction in Terry's New Theatre.** By Max Am Ende. Gives description, with drawings of details of the ironwork in Terry's new theatre in London. *Engineer*, Oct. 7, 1887.
- Irrigation.** By M. J. Mack. An interesting description of the Montezuma Valley, Colo., with illustrated details of the irrigation works now being constructed. *Eng. News*, Dec. 31, 1887.
- , *Evils of Canal, in India.* By T. H. Thornton, before the Society of Arts. Discusses the evils arising from canal irrigation in India, viz.: impoverishment of soil, waterlogging and poisoning, and malarial influences, and suggests remedies for them. *Jour. Soc. Arts*, March 23, 1888.
- , *Injurious Effects on Health in India.* By Surg. Gen. H. W. Bellew, before the Society of Arts. Gives results of personal observation of the injurious effects of canal irrigation on the health of the population of the Punjab, and their remedy: *Jour. Soc. Arts*, May 11, 1888.
- , *in Indid.* See Agricultural Engineering in India.
- , *Machinery on the Pacific Coast.* A paper by John Richards, before the Institution of Mechanical Engineers. Describes the methods employed in irrigation and then discusses the different kinds of machinery used. *Engineering*, Nov. 4 et seq.; *Sci. Am. Sup.*, Dec. 17 et seq., 1887.
- Kinometer, Hayne's.** An illustrated description of Hayne's kinometer. It is intended to serve the purpose of a speed indicator, recorder and governor. *Rail-road Gazette*, Nov. 18, 1887.
- Lubricants.** By J. E. Denton. A paper before the Nashville meeting of the American Society of Mechanical Engineers, discussing the mechanical significance of the determination of viscosity. *Trans. Am. Soc. Mech. Engr.*, Vol. IX. (1883), pp. 369-376; *R. R. Gazette*, May 11, 1888; *Amer. Engr.*, June 13, 1888.
- , Gives tables showing proportion of various oils commonly used for lubrication. *Engineering*, April 20, 1888.
- , See Car Axles.
- Lamps, Maximum Efficiency of Incandescent.** See Electric Light.
- Latimer, Charles, Eulogy upon the Life of.** By W. H. Searles, before the Civil Engineers' Club of Cleveland. *Jour. Assoc. Engin. Soc.*, June, 1888, Vol. VII., pp. 201-207.
- Lattice Girders, Stresses in.** See Bridge.
- Least Squares.** On some simplifications which may be made in the application of the method of least squares. By Dr. Nell. *Zeitschr. f. Vermessungswesen*, 1887, pp. 454-467.
- Levee, Davis Crevasse.** By S. F. Lewis, before the American Society of Civil Engineers. Gives details of the break in Davis levee, near New Orleans, and the method adopted in its repair. *Trans. Am. Soc. C. E.*, Oct., 1888, pp. 199-204.
- Levees of the Mississippi River.** By Caleb G. Forshay. Gives outlines of history

- of levees on the Mississippi; discusses the forms and dimensions and what is required of a levee. A valuable paper. *Trans. Am. Soc. C. E.*, Vol. III. (1874), pp. 267-284.
- Light-House, Rothersand.** By O. Offergeld, 'before the Association of Architects and Engineers, at Hamburg. Gives details of the construction of the Rothersand light-house in the North Sea, with two-page plate showing plans and sections of the pneumatic caisson. Valuable. *Engineering*, Dec. 2 and 16, 1887.
- Lighting Railroad Trains.** Abstract of the report on car lighting presented at the International Railroad Congress held at Milan, in September. *Railroad Gazette*, Nov. 18, 1887.
- Lightning, Protection of Buildings from.** A lecture by Prof. Oliver J. Lodge before the Society of Arts. *Jour. Soc. Arts*, June 15, 1888.
- Liquid Fuel for Gas Retorts.** Gives details of experiments made on burning coal tar under gas retorts with the Drury spray nozzles. Illustrated. *Engineer*, Sept. 7, 1888.
- Locomotive. Circulation in Boilers.** By John Hickey, before the Western Railway Club. Discusses the proper construction of locomotive boilers and fire-boxes to obtain the most economic results. *Master Mechanic*, October, 1888. Discussion on this paper in *Master Mechanic* for November.
- , **Compound.** Gives plan, elevation and cross-section of a compound locomotive, Warsdell and Von Borries system, of the Bengal & Nagpor Railroad. *Engineer*, July 20, 1888.
- , **Compound Express.** Gives a two-page plate showing sectional elevation and plan of a compound express locomotive built for the Northeastern Railway, Eng. *Engineering*, March 30, 1888. Details of tests of these engines in *Engineering*, April 13, 1888.
- , **Compound Tank.** Gives two-page plate of elevation and plan, with dimensions, and brief description of a freight locomotive, Webb's system and Joy's valve motion, for the London & Northwestern Railway. *Engineering*, Dec. 23, 1887.
- , **Distribution of Steam in the Strong.** By F. W. Dean, before the American Society of Mechanical Engineers. Abstracted, *R. R. Gazette*, May 25, 1888.
- Locomotives, Draft Appliances in.** A paper by F. C. Smith before the April meeting of the Western Railroad Club. Gives results of experiments made on a number of engines to see what could be done to obtain a better efficiency. Discussion. *R. R. Gazette*, April 20, 1888; *Master Mechanic*, May, 1888; *Nat. Car and Loco. Builder*, May, 1888.
- , **Estrade's High-speed.** An illustrated description and criticism of Estrade's high-speed locomotive. It has six driving wheels 6' 3" in diameter, cylinders $18\frac{1}{2} \times 27\frac{1}{2}$, with a weight of 42 tons. *Engineer*, March 9, 1888; *Sci. Am. Supple.*, April 23, 1888.
- , **Express, Baltimore & Ohio.** Gives a brief description, with two-page plate, and extracts from the specifications of a new eight-wheel locomotive built for the Baltimore & Ohio Railroad. Its dimensions are: Cylinders, 19 by 20 in.; drivers, 66 in.; boiler, 53 in.; tubes, 174; weight on drivers, 70,000 lbs.; total weight, 102,000 lbs.; *Master Mechanic*, May, 1888.
- , **Express, Caledonian Railway.** Gives brief description of an express engine that made 101 miles in 104 minutes. Cylinders, 18×26 in.; driving-wheels, 84 in.; weight, 94,000. *R. R. Gazette*, Aug. 24, 1888.
- , **Express, C. & N. R. R.** Gives brief description, with two-page plate, giving sectional elevation, half plan and cross-section of a passenger locomotive for the Chicago & Northwestern Railroad. *R. R. Gazette*, Dec. 23, 1887.
- , **Express, Mich. Cent. R. R.** Brief description, with drawings, showing sectional elevation, half-plan and cross-section of a standard eight-wheeled passenger engine for the Michigan Central Railroad. *Mast. Mech.*, August, 1887.
- , **Express, Midland R. R.** Two-page plate giving sectional plan and elevation, with dimensions of an inside cylinder, four-coupled type of express engine for the Midland R. R. Co. *Engineering*, Dec. 9, 1887.
- , **Express, N. Y., L. E. & W.** Gives double-page plate showing elevation and half-plan, also smaller drawing showing sections and details with dimensions. *R. R. Gazette*, Jan. 6, 1888.
- , **Express, Ten-wheel, M. C. R. R.** Gives elevation of a ten-wheel locomotive

built for the Michigan Central Railroad, with specifications giving the leading dimensions. *R. R. Gazette*, Feb. 24, 1888.

Locomotive, Express, Wootten, U. P. R. R. Brief description, with detailed drawings of passenger engines with the Wootten fire-box built for the Union Pacific Railroad. Cylinders, 18 by 26 inches; drivers, 63 inches; weight on drivers, 76,500 pounds; total weight, 118,500 pounds. *R. R. Gazette* June, 15, July 6, Aug. 11, Sept. 7 and Oct. 5, 1888.

—, **Freight, C., B. & N. R. R.** Gives a two-page plate showing sectional elevation and half plan, other cuts showing cross sections of a ten-wheel locomotive of the Chicago, Burlington & Northern Railroad. *Master Mechanic*, December, 1887.

—, **Freight, N. N. & M. V. R. R.** Give specifications for a ten-wheeled freight engine for the Newport News & Mississippi Valley Company. Drawings with dimensions showing elevation of engine, also details of coupling, connection and eccentric rods, rocker box, crank pins, links, etc. *Railroad Gazette*, March 16, 1888.

—, **Freight Mogul, D., L. & W. R. R.** Gives short description, with elevations and cross-sections, and dimensions of a freight engine, of the Mogul type, for the Delaware, Lackawanna & Western Railroad. *R. R. Gazette*, Feb. 3, 1888.

—, **Hungarian State Railroads.** Gives a two-paged plate, showing sectional elevation and plans of a tank locomotive, of which 60 are in use on the Hungarian state railroads. They evaporate $4\frac{1}{2}$ lbs. per sq. ft. per hour, and haul 280 tons up incline 1 in 150, at a speed of 13 miles per hour. *Engineer*, Feb. 3, 1888.

—, **Imperial Railroads, Japan.** A two-paged plate showing sectional elevation and plan of a tank locomotive for the imperial railroads of Japan. They are 3 feet 6 inches gauge, two pairs drivers 4 feet 4 inches in diameter, 14×20 inch cylinder; weigh $32\frac{1}{4}$ tons, with 20 tons coupled to wheels. *Engineering*, Feb. 10, 1888.

—, **Indian State Railroad.** Gives brief description, with plan and elevation, of a six-coupled metre gauge locomotive for the Indian State Railroad. *Engineer*, March 27, 1888.

—, **Light Tramway.** Gives brief illustrated description of the locomotives used on the Cavan, Leitrim and Roscommon tramway, Ireland. *Engineer*, April 20, 1888.

—, **Lancashire and Yorkshire.** Gives longitudinal section and description, with dimensions of engine and tender, of a passenger engine for the Lancashire and Yorkshire Railway Co. *Engineer*, Aug. 26, 1887.

—, **London and Southwestern.** Gives description and specifications, with a two-page plate of detailed drawings of a four-coupled, outside cylinder locomotive, *Engineer*, Nov. 4 and 11, 1887.

—, **Passenger, C., B. & Q.** Gives a description, with drawings, showing sectional elevation, half-plan and eight half-section of a heavy passenger engine, Mogul type, weighing 110,000 lbs., for the C., B. & Q. Railroad. *Master Mechanic*, February, 1888.

—, **Passenger, N. Y., L. E. & W. R. R.** Gives elevation, half-plan and three cross sections, with brief description, of a high-speed passenger engine for the New York, Lake Erie & Western Railroad. It has two pairs of 68-inch drivers, cylinder 19×24 , and weighs 115,000 lbs., with 78,000 on the drivers. *Nat. Car and Loco. Builder*, April, 1888.

—, **Passenger, Caledonian Railroad.** Gives half plan, elevation and cross-section of a passenger locomotive for the Caledonian Railroad. It has two pairs 5 ft. 9 in. drivers, cylinders 18×26 in., and weighs 83,000 lbs. *Engineer*, April 13, 1888.

—, **Passenger Ten-wheel.** Gives drawing and description, with specification of ten-wheel locomotive built by the Schenectady Locomotive Works for the Colorado Midland Railroad. *Railroad Gazette*, Nov. 25, 1887.

—, **Philadelphia & Reading R. R.** Gives outlines engraving of the four classes of new locomotives to take the place of the Wootten locomotives on the Philadelphia & Reading Railroad. *Nat. Car and Loco. Builder*, April, 1888.

—, **Road, McLaren's High-Speed.** Describes a compound 12 horse-power road engine working with a pressure of 175 lbs. *Engineer*, Dec. 16, 1887.

—, **Strong.** A brief description of the Strong locomotive. Illustrated, with reasons for the peculiar features in its design. By George S. Strong. Also a summary of the results of trials of the engine on the Lehigh Valley Railroad, made by E. D. Leavitt. *The Journal of the Franklin Institute*, February, 1888.

- Locomotive, Tramway.** Describes a small, powerful condensing engine for street work. Illustrated. *Engineer*, Oct. 21, 1887.
- , *Tramway.* Brief illustrated description of Burrell's tramway locomotive, that gave very good results in Birmingham. *Engineer*, Oct. 28, 1887.
- , *Test of.* Gives details of a test made of a locomotive on the New Jersey Central Railroad, by Messrs. H. S. Wynkoop and John Wolff, with tables and indicator diagrams. *R. R. Gazette*, Aug. 17, 1888.
- , *Tests Comparing Radial Motion and Link Motion.* By Angus Sinclair. Gives details of test trips made on the Burlington, Cedar Rapids & Northern Railroad, with engines of similar dimensions but equipped with different valve-gear. Gives 38 indicator diagrams. *Nat. Car & Loco. Builder*, April, 1888.
- , *Compound.* Gives a method of computing the mean pressures. *Mech. World*, March 10, 1888.
- , *Coupling and Connecting Rods.* A series of papers on the proper design of coupling and connecting rods for locomotives. *Engineer*, May 25 *et seq.*, 1888.
- , *Cost of Rebuilding.* Gives details of the cost of rebuilding a locomotive at the Ohio & Mississippi railroad shops at Vincennes, Ind. Also an editorial on the subject. *R. R. Gazette*, Oct. 19, 1888.
- , *Counterbalancing of.* By Prof. Lanza, before the Scranton meeting of the American Society of Mechanical Engineers. Gives results of experiments on the effects of different methods for counterbalancing the reciprocating parts of a locomotive. *Master Mechanic*, November, 1888; *R. R. Gazette*, Oct. 19, 1888.
- , *Extension Fronts and Fire-Box Arches.* Gives the report of the committee of the Master Car-Builders' Association on extension fronts and fire-box arches. *R. R. Gazette*, June 22, 1888; *Nat. Car and Locomotive Builder*, July, 1888; *Master Mechanic*, July, 1888.
- , *Extension Front of.* Gives sectional drawings with dimensions of the extended front on the Fremont, Elkhorn & Missouri Valley Railroad. Also, discussion of the different forms of smoke-boxes by the Western Railroad Club. *Nat. Car and Loco. Builder*, December, 1887.
- , *High and Low.* By Prof. A. G. Greenhill. A mathematical treatment of why a high locomotive will run with greater safety and steadiness than a low one. *Engineer*, Dec. 2, 1887.
- , *Specifications for.* Gives drawing-room specifications for express locomotives built at the Baldwin works, for the New York, New Haven & Hartford Railroad. *Master Mechanic*, September, 1888.
- , *Water for, and Practice in Washing out Boilers.* By G. A. Gibbs, at January meeting of Western Railway Club. Treats the subject from a practical point of view. Gives some experience gained by the Chicago, Milwaukee & St. Paul Railroad. *R. R. Gazette*, Jan. 20, 1888.
- Machine Construction, Milling Machine as a Substitute for the Planer in.** By J. J. Grant before the American Society of Mechanical Engineers. Gives data relating to the cost of work on the two machines. Shows the milling machine to be the cheaper. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 259-269; abstracted in *R. R. Gaz.*, Jan. 6, 1888; *Mech. World*, Dec. 17, 1887.
- Machine Designing.** By John E. Sweet. A lecture delivered before the Franklin Institute. Illustrated. *Sci. Am. Supple.*, April 28, 1888; [abstracted *R. R. Gaz.*, June 15, 1888.
- Magnetism** See Watches, Protection of; also Paillard's Non-Magnetic Balances and Hair Springs for.
- Manganese Steel.** See Steel.
- Measures, Standard.** By E. A. Gieseler. Gives brief history of the development of standards of length, describes the present standards of the United States and the methods adapted to compare them with other standards, etc. *Jour. Franklin Institute*, August, 1888; *Engr. News*, Sept. 8, 1888.
- Mechanical Engineering, Chalk Age of.** By J. T. Holloway. Fifth lecture before the students at Cornell University. Gives picture of engineering practices of days gone by and the contrast between the former and modern practice. *Sci. Am. Supple.*, June 16, 1888.
- Mechanical Engineers, Advice to Young.** By Prof. Perry to the students at Finsbury Technical College. A valuable paper for working engineers, *Sci. Am. Supple.*, Sept. 1, 1888.

- Metallic Compounds.** A long list of authorities on metallic compounds may be found in the *Report of U. S. Board of Testing Iron, etc.*, Vol. I., 1881, pp. 149-210.
- Meter, Forbes'.** Description of various forms and analysis of patent claims. By Prof. Edwin J. Houston. Also paper by Prof. George Forbes, describing his electrical current meter, read before the Franklin Institute, Oct. 19, 1887. *Journal of the Franklin Institute*, Dec., 1887, Vol. CXXIV., No. 744.
- See Water Meters.
- Milling, Modern.** By Gilbert Little. An illustrated series of articles dealing with the birth and development of the Hungarian or Semolina system. *Engineer*, July 15, etc., 1887.
- Mineral Production for 1887, Statistics of.** Good summaries of the production and prices of zinc, copper, coal, coke and pig-iron for the past year will be found in *Eng. and Min. Jour.*, Jan. 7, 1888.
- Mining Appliances in Westphalia.** By Messrs. Malkel, De Gournay and Suisse. Gives notes on the machinery, appliances, mode of working, etc., of the collieries of Westphalia. *Proc. Inst. C. E.*, Vol. XCII., pp. 367-376.
- *Mica in North Carolina.* By Wm. B. Phillips. A series of papers describing the geology of the mining districts, formation of the veins, dressing the mica, etc. *Engin. and Min. Jour.*, April 21 *et seq.*, 1888; *Sci. Am. Supple.*, July 21 *et seq.*, 1888.
- *Ores and their Mode of Occurrence at Aspen Mountain, Colo.* By D. W. Bounton. A series of illustrated articles describing the ore deposits and the faulting of the Aspen district, Colorado. *Engin. and Min. Jour.*, July 14 *et seq.*, 1888.
- *Ore Deposits of Red Mountain, Colo.* By G. E. Kedzie before the American Institute of Mining Engineers. Gives a description of the bedded ore deposits of Red Mountain mining district, Colo. *Engin. and Min. Jour.*, Aug. 11, 1888.
- *Systems of, in Large Bodies of Soft Ore.* By R. P. Rothwell, before the Boston meeting of the American Institute of Mining Engineers. Describes the system employed at the Dean River mine and proposes working the vein out from the top down instead of from the bottom up. *Engin. and Mining Jour.*, March 10, 1888.
- *Theory of Shot-Firing in.* By M. P. F. Chalon. Gives a general theory of shot-firing with common powder or high explosives. *Eng. News*, Jan. 14, 1887.
- Mining Engineering.** By J. L. Culley. A paper involving the general principles of mining engineering, relating particularly to coal bank work as pursued in Ohio. *Engin. News*, March 10, 1888.
- Mortar. Efflorescence and Impervious.** By Ira O. Baker. Gives reason of efflorescence and discusses its remedy. Also discusses the use of soap and alum to render brick and mortar impervious. *Engin. News*, April 7, 1888.
- *Making and Using.* By B. F. Bowen. Contains much useful information relative to lime mortar. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 223-31.
- Moment Diagram for Bridge Strains.** See Bridge Strains.
- Motor, Mekarski's Compressed Air.** Gives an illustrated description of the Mekarski compressed air motor for street railroads, several of which are now working on a London road. *Engineering*, March 23, 1888.
- *Thermo.* See Engine.
- *Parson's Steam Turbine.* Gives description with results of the practical working of Parson's steam turbine. The best results so far attained are a consumption of 52 pounds of steam an hour for each electric horse-power with steam at 90 pounds pressure above the atmosphere. *Engineering*, Jan. 13, 1888; *Sci. Am. Sup.*, Feb. 11, 1887.
- *Triple Thermic.* By Chas. H. Haswell before the American Society of Civil Engineers. Gives description, operation and results of a single expansion, non-condensing steam engine, supplemented by the evaporation of bisulphide of carbon and expansion of its vapor. *Trans. Am. Soc. C. E.*, Vol. XVII., pp. 193-199, October, 1888; *Sci. Am. Supple.*, April 14, 1888; *Engineer*, June 1, 1888.
- *for Alternating Currents.* See Electric Motors.
- See Dynamo.
- Masonry, Proper Construction and Cost of.** By T. H. McKenzie, before the Connecticut Association of Civil Engineers and Surveyors. Gives specifications, with comments, for first-class masonry. *Proc. Conn. Assoc. C. E. & Surt.*, 1888, pp. 45-54.

- Masonry and Stone Cutting.** By Law. Harvey. A series of articles giving instruction in the draughting of details of masonry. *Build. News*, Dec. 11 *et seq.*, 1887.
- Municipal Engineer and the Management of his Office.** By B. Schreiner. Gives good hints relative to the management of the offices of city engineers. *Jour. Assoc. Engr. Assoc.*, January, 1888, pp. 9-12. *Engin. and Build. Rec.*, May 12, 1888.
- Masonry, Government Specifications for.** Gives the regular specifications for stone work in use in the Government architect's office. *Eng. News*, June 2, 1888.
- Oil Burners for Steam Boilers.** Abstract of a series of papers by Herr Busley, of Kiel, a marine engineer, describing the leading or typical devices which have been and are used for burning liquid fuel, under the following classification: 1. Hearth fires. 2. Gas fires. 3. Spray fires. *Railroad and Engineering Journal*, April, May, June 1888.
- Oil Wells.** See Gas.
- Ordnance.** *The Zalinski Pneumatic Torpedo Gun.* Extracts from a paper by Capt. E. L. Zalinski, U. S. A., read before the U. S. Naval Institute, December, 1887, on the Naval Uses of the Pneumatic Torpedo Gun. *Railroad and Engineering Journal*, May, 1888.
- Ore Sorting.** By T. L. Bartlett. Gives a description of the method of ore sorting employed at Milan mine. *Eng. & Min. Jour.*, April 14, 1888.
- Ore-Deposits, Forms of, in Limestone.** By Carl Henrich. Describes the peculiar form of galena deposits in Missouri. *Eng. and Min. Jour.*, Nov. 3, 1888.
- Ore-Deposits, Geology of the Aspen, Col.** By L. D. Siver. *Engin. and Mining Jour.*, March 17 *et seq.*, 1888.
- Ore, Dressing of Non-Bessemer.** By G. W. Maynard and W. B. Kunhardt. *Engin. and Mining Jour.*, March 31 *et seq.*, 1887.
- See Mining.
- Pantagraph; Its Theory and its Use.** By E. A. Gieseler. *Eng. News*, Nov. 26, 1887.
- Passenger Car Truck.** Gives detailed drawings with dimensions of a passenger truck with eight brake shoes. *R. R. Gaz.*, Dec. 9, 1887.
- Patents. Reforms needed in the U. S. Patent Office.** Report of the Legal Committee of the National Electric Light Association on the above subject at the Pittsburgh meeting. *Electrical Engineer*, March, 1888; *Electrical World*, March 3, 1888.
- Pavements, Asphalt.** A report by W. P. Rice to the Board of Improvement of Cleveland on the use of Asphalt Pavements. *Engin. and Build. Rec.*, May 26, 1888.
- , *Asphalt and Concrete Foot.* By G. R. Strachan, before the Association of Municipal and Sanitary Engineers and Surveyors, at Leicester. Gives details of experiments with asphalt walks in England, with data of durability, cost, etc. *Sci. Am. Sup.*, Dec. 31, 1887.
- , *Cleveland, O.* By M. E. Rawson. Describes the methods of construction, specifications and durability of the Cleveland pavements. *Rpt. Ohio Soc. Surr. and Engs.*, 1888, pp. 70-95.
- , *Sydney, N. S. W.* By A. C. Mountain. Before the Institution of Civil Engineers. Gives details of the pavements, principally wooden, of the city of Sydney, New South Wales; also description of and results of tests on Australian timber. *Proc. Inst. C. E.*, Vol. XCIII., pp. 364-382.
- Paving, Valuation of Road Metal and Setts for.** By W. F. Stock. Discusses the salient features to be looked at in selecting road material, and gives results of examinations made with a machine for testing the abrasion resistance of road metal. *Eng. News*, Sept. 22, 1888.
- , *Notes on.* By T. R. Wickenden. Object of paper is to call attention to desirable as well as objectionable qualities of various pavements in general use. *Rpt. Ohio Soc. Surr. and Engs.*, 1888, pp. 69-75.
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- , *Specification for Material.* Gives specifications for the supply and delivery of wood blocks for paving portions of the street known as King's road and Pont street, in Parish of Chelsea. *San. Engr.*, Dec. 31, 1887.

- Pavements, Specification for Wood.** Gives specifications for wood pavement in Parish of St. George, London. Said to be one of the best recently written. *San. Engr.*, Dec. 24, 1887.
- , *Wood in Paris.* Gives a translation of the specifications and principal instructions issued in 1886. *Eng. and Build. Rec.*, June 9, 1888.
- , *Wood in Paris.* An abstract from a paper by M. A. Laurent in *Genie Civil* gives details of the present practice of paving with wood in Paris. *Eng. & Build. Rec.*, April 7, 1888.
- Permanent Way.** See Railroads.
- Petroleum, Transportation of, in Russia.** Gives a detailed account of the proposed 8-in. pipe line from Baku to Port of Batam. Length of line 497 miles, with 24 stations, each of which contain four 150 horse-power engines. Delivery estimated at 110 cub. ft. per minute. *Engineering*, Feb. 3, 1888.
- Pier, Marine Park, Boston.** Short description, with full detail drawings, of the iron pier at Marine Park, Boston. It has twelve spans, 60 feet each, resting on cast-iron pins filled with concrete. *Engin. and Build. Rec.*, Jan. 28, 1888.
- , *St. Leonards-on-Sea.* Gives brief description, with drawing of details of a screw pile promenade pier 900 ft. long and 25 ft. wide, being built at St. Leonards-on-Sea, England. *Engineer*, May 11, 1888; *Sci. Am. Supple.*, June 23, 1888.
- Pig Iron.** See Iron.
- Pile Trestles.** Gives detailed drawings of the standard trestle of the Chicago, Burlington & Northern Railroad. *Engin. News*, May 5, 1888.
- Piles, Supporting Power of.** By Prof. J. O. Baker. Discusses the formula of Mr. Trautwine, and shows its defects. Gives an empirical formula derived by Mr. Hertz from driving of over 400 piles. *R. R. Gazette*, April 6, 1888.
- , *Protection of, from Limnoria and Teredo.* By M. Manson, before the American Society of Civil Engineers. Gives details of the treatment of piles for the Mission street pier, San Francisco, by various methods, and the condition of piles after five year's service. An abstract in *San. Engr.*, Dec. 31, 1887; *Engineer*, Jan. 6, 1888.
- Pipe. Standard Pipe and Pipe Threads.** Report of a committee of the American Society of Mechanical Engineers, read at their New York meeting, November, 1876. Recommends the adoption of the Briggs standard, already in quite general use. *Transactions of the American Soc. of Mechanical Engineers*, Vol. VIII., 1887.
- , *Strength of a Copper Steam.* Gives an abstract from a report for the Board of Trade Surveyors on the testing of a copper steam pipe taken from a steamship. *Engineering*, Sept. 14, 1888.
- , *Copper, Strength of.* Gives table of results of a large number of tests made at the Lancefield Engine Works to ascertain some of the mechanical properties of the copper and brazing found in ordinary high-pressure steam pipes of large size. *Engineering*, Dec. 31, 1887.
- Piping.** See Water-Works.
- Planimeter, Corade's Rolling.** By Prof. F. Loeber. A description and theoretical study of Corade's rolling planimeter. *Zeitschr. f. Vermessungswesen*, 1887, pp. 377-383; 421-437.
- , *New Spherical.* By Prof. Hele Shaw. Gives an illustrated description, with theory of action, of a new spherical planimeter. *Engineering News*, Oct. 13, 1888.
- , *Polar.* E. A. Gieseler. Gives a mathematical discussion of the theory and use of the polar planimeter. *Sci. Am. Supple.*, March 17, 1888.
- Plumbing, Specifications for.** Gives specifications of the Board of Health for plumbing in New York City. *Engin. & Building Rec.*, July 21, 1888.
- Pneumatic Foundation of a Tidal Basin Entrance Lock at Dieppe, France.** Under over 55 feet head of water; area of caisson, about 120 feet by 115 feet. *Annales des P. and C.*, November, 1887.
- Pontoons.** See Docks.
- Power, Hydraulic in London.** By Baggand Ellington, before the Institution of Civil Engineers. Gives a description of plant of Hydraulic Power Company of London. *Engineer*, May 11, 1888; *Engineering*, April 27, 1888; *Am. Engr.*, June 27, 1888; *Mech. World*, May 12, 1888; *Engin. and Min. Jour.*, Nov. 3, 1888.

- Power, Press Problems.** By Oberlin Smith, before the Philadelphia meeting of the American Society of Mechanical Engineers. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 161-171.
- Propulsion of Ships by Air Propellers.** By H. Vogt before the Bath Meeting of the British Association. Gives details of experiments made with propellers working in the air instead of the water. *Engineer*, Sept. 28, 1888.
- , *On the Laws of Steamships.* *Engineer*, July 27, 1888.
- Propellers.** A paper by C. Trathen on the practical geometry of the screw propeller. *Mechanical World*, Feb. 4, 1888.
- Public Works, Cullom-Breckenridge Bill.** Arguments on the Cullom-Breckenridge Bill by a Committee of the St. Louis Engineers' Club. A pamphlet of 19 pages. Copies may be had by addressing Prof. J. B. Johnson, St. Louis, Mo.
- Pumps, Centrifugal, their efficiencies.** By Wm. O. Webber before the American Society of Mechanical Engineers. Gives details of experiments made upon centrifugal pumps. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX., pp. 228-246.
- , See Water-Works.
- , *Mercurial Air.* By Prof. S. P. Thompson, before the Society of Arts. A very complete paper, tracing the development of the mercurial air pump. Gives cuts of the various machines and the results attained with some of them. *Jour. Soc. of Arts*, Nov. 25, 1887; *Sci. Am. Sup.*, Jan. 21 *et seq.*, 1888. Abstracted *Engineering*, Nov. 25, 1887.
- Pumping, Electric.** Brief description of an electrical pumping plant at St. John Colliery, Normanton, Eng. Efficiency, 44.4 per cent. *Engineer*, Dec. 2, 1887.
- , *Electric, in Collieries.* By Frank Brain, before South Wales Institute of Engineers. Gives details of the pumping plant at the Trafalgar collieries. Gives an analysis of the work done, showing the per cent. lost in different parts of plant; also gives comparison of cost of underground haulage by electricity, cables, compressed air and hydraulics. *Mech. World*, Dec. 24, 1887; *Am. Engineer*, Jan. 11 and 18, 1888.
- Pumping Engine, Chicago.** The report of Mr. F. W. Gerecke to the Commissioner of Public Works on the condition and capacity of the pumping engines of the water-works. *Am. Engr.*, March 14 *et seq.*, 1888.
- Pumping Engines, Whampoa Docks.** Brief illustrated description of the large centrifugal pumping engines in use at Whampoa Docks, Hong Kong. *Engineer*, Nov. 18, 1887.
- , *Leicester.* Specifications for the erection of pumping engines, etc., for the Beaumont Lego pumping station, Leicester. *Engineer*, Aug. 12, 1887.
- Pumping Machinery. Types of Hydraulic Pumping Machinery.** By J. T. Fanning. A short historical and descriptive paper, with cut showing an improved form of turbine pumping machinery. *Jour. New Eng. W. Works Assoc.*, Sept., 1886.
- Propellers, Experiments with Screw.** By J. B. Andreae, before the Institute of Naval Architects. Gives details of experiments with four and two-bladed propellers. *Engineering*, April 13, 1888; *Sci. Am. Sup.*, May 19, 1888.
- Railroad, Abt System, Indian Experiments.** Gives details of experiments made on a section railroad built on the Abt system over the Bolan Pass. *Engineer*, July 13, 1888.
- , *Canadian Pacific.* The annual address of the President of the American Society of Civil Engineers, Mr. T. C. Keefer, read at the annual convention of 1888. Gives details of construction of the Canadian Pacific Railroad. Abstracted in *R. R. Gazette*, July 6, 1888. Also *Sci. Am. Supple.*, Aug. 4, 1888.
- , *European, as they Appear to an American Engineer.* W. H. White. Gives brief description of some of the most prominent features in the construction and workings of the European railroads. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., p. 61.
- , *Inclined, Lookout Mountain.* By W. H. Adams, before the American Society of Mechanical Engineers. Gives full description of the inclined railroad up Lookout Mountain, Tenn., with profile and plan of road, engine plant and details of cars, etc. *Eng. News*, Jan. 7, 1888; *Sci. Am. Supple.*, May 12, 1888; *Engineering*, March 30, 1888. Abstracted *Proc. Inst. C. E.*, Vol. XCII., pp. 463-4.
- , *Lartigue System.* Gives brief description of Listowel & Ballybunion Railroad, Ireland. It is 10 miles long and built on the Lartigue single rail system.

- Gives cuts of rolling stock and details of roadbed. *Engineer*, March 2 and 9, 1888. *Sci. Am. Supple.*, April 7, 1888.
- Railroad, Gauges of the World.** An abstract from an article by Herr Claus in *Glaser's Annalen*, showing the history and development of the railroad gauges of the world. *R. R. Gazette*, Sept. 14, 1888.
- , *Pacific, and the Government.* Editorials showing how the present difficulties have arisen, and examines the plans proposed for their salvation. *R. R. Gazette*, Jan. 27 *et seq.*, 1887.
- , *Signals, Automatic.* Gives a description of the automatic signals in use on the Fitchburg Railroad, Mass. *R. R. Gazette*, June 15, 1888.
- , *Switch, Standard Point.* Gives full detailed drawings of the standard point switch of the Boston & Albany Railroad. *R. R. Gazette*, March 2, 1888; *Engin. News*, March 31, 1888.
- , *Building a Second Track.* By H. C. Thompson, before the Civil Engineers' Club of Cleveland. Discusses the question of building an additional track to a single track railroad already in operation. *Jour. Assoc. Engin. Soc.*, April, 1888.
- , *Classification of Accounts, etc.* By G. Mordecai, before the American Society of Civil Engineers. Gives notes on the classification of railroad accounts and the analysis of railroad rates. *Trans. Am. Soc. C. E.*, Vol. XVIII., February, 1888, pp. 62-68.
- , *Cause of Shock.* By H. Hollerith. Discusses the shock produced in stopping trains in the light of the theory of impact. *R. R. Gazette*, April 27, 1888.
- , *Depreciation of Freight Cars.* Gives a table showing the value of a freight car at any age, estimated at 6 per cent. per annum as per Master Car-Builders' rules. *R. R. Gazette*, April 27, 1888.
- , *Effect of rail upon wheel, and of wheel upon rail.* Review of book by Boedeker, Hanover, 1887. Hahn, publisher.
- , *Freight-car Couplers.* Gives text of the progress report of the Shinn Committee on Uniform Couplers. *R. R. Gaz.*, Dec. 9, 1887.
- , *Frogs and Switches.* By W. F. Ellis, before the January meeting New England Railroad Club. Discusses and advocates the use of spring-rail frogs. Discusses safety switches and advocates the split or point switch. *Master Mechanic*, Feb., 1888.
- , *Frogs and Safety Switches.* By Geo. Richards, before the New England Railroad Club. Discusses the development of switches and frogs, and gives the qualities of a good safety switch. *Master Mechanic*, February, 1888.
- , *German Switch Movement.* Gives a translation of a lecture before the Berlin Railroad Club discussing the arrangements by which a close contact in split switch worked from a distance is obtained. *R. R. Gazette*, Aug. 10, 1888.
- , *Interlocking Apparatus, L. I. R. R.* Gives a brief description with illustrated details of the interlocking apparatus on the Long Island Railroad. *R. R. Gazette*, Feb. 10, 1888.
- , *Interlocking Switches and Signals.* By Charles R. Johnson. A series of papers showing the progress made in the use of interlocking switches and signals, and the modifications in practice. *R. R. Gazette*, May 4 *et seq.*, 1888.
- , *Journal Friction and Train Resistance on.* An address before the March meeting of the Western Railroad Club by G. W. Rhodes. *Master Mechanic*, April, 1888.
- , *Maintenance of Track.* By John M. Goodwin. An attempt to show the relation existing between the cost of track maintenance and the use of steel rails. *R. R. Gazette*, May 4, 1884.
- , *Ruling Gradient.* By E. Holbrook. Discusses how to determine the best gradient for a railroad. *Sci. Am. Supple.*, July 21, 1888; *R. R. Gazette*, July 27, 1888.
- , *Steel Ties.* By J. W. Post. Before the annual convention of the American Society of Civil Engineers. Gives cost of maintaining track on steel ties on the Netherlands State railroads. *Engin. News*, June 30, 1888.
- , *Permanent Way.* Gives a summary of returns received in reply to circular issued under a resolution pertaining to roadway adopted at a meeting of the Association of North American Railroad Superintendents, Oct. 11, 1887. *R. R. Gazette*, April 13, 1888.
- , *South African.* Gives map showing their location and data of population, trade, etc. *R. R. Gaz.*, Nov. 25, 1887.

- Railroad, Lighting of Stations.** Abstract from a report to the International Railroad Congress, Milan Session, 1887. Discusses the use of gas and electricity. *R. R. Gaz.*, Jan. 6, 1888.
- , *Lighting and Ventilation.* Discussion of the above subjects by the New York Railroad Club. *R. R. Gazette*, Nov. 25, 1887.
- , *Locomotive and Car Shops, C., St. P. & K. C. R. R.* Gives general and detailed plans of the locomotive and car shops of the Chicago, St. Paul & Kansas City Railroad at St. Paul. *R. R. Gazette*, Feb. 10, 1888.
- , *Ratio of Population to Mileage.* By W. H. White. Gives diagram showing the ratio of population to railroad mileage, and the probable increase of mileage demanded. *R. R. Gazette*, Oct. 5, 1888.
- , *Relative Cost of Transporting Car-loads and Less than Car-load Lots.* Gives the testimony of Mr. Fink before Inter-State Commerce Commission. Submitted a statement based upon statistics. A valuable paper. *R. R. Gazette*, Feb. 3, 1888.
- , *Rolling Stock and Tramways, Guinness Brewery.* By S. Geoghegan, before the Institute of Mechanical Engineers. Gives a full description, with detailed drawing, of the rolling stock and tramways at a brewery in Dublin. *Engineer*, Aug. 31, 1888.
- , *Swedish.* By W. Koersner. Treats of the railroads of Europe, but more especially with the development of the railroads in Sweden. Maps and tables of revenues, etc. *Engineering*, Jan. 6, 1888.
- , *Wheel Tires and Rails, Wear of.* By Richard Helmholtz. Discusses the wear on wheel-tires and rails on curves, and rolling stock appliances for reducing the same. *Zeitschrift des Vereines deutscher Ingenieure*, 1888, pp. 330-353; abstracted *Proc. Inst. C. E.*, pp. 549-554.
- Railway on Suspended Cables.** *Annales des P. and C.*, November, 1887.
- Railroad Bed for Bridge Structures.** Abstract of a paper by O. C. Woolson, before the Philadelphia meeting of the American Society of Mechanical Engineers, describing an elastic floor system which has been tried on the elevated roads of New York. Illustrated. *Trans. Amer. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 276-285; *R. R. Gazette*, Dec. 30, 1887.
- Railroading, Scientific.** By Gen. J. H. Wilson. Reviews the present position of railroading as a science and enters a plea for a good railroad school. *R. R. Gazette*, Dec. 30, 1887.
- Railroad Construction.** Gives a list of all railroad lines in United States, Canada and Mexico, on which track was laid during 1887, with a two-page map printed in colors, showing track laid from beginning of 1886 to June 15, 1888. *Engin. News*, June 16, 1888. See also Tabulation in *Railroad Gazette*, June 1 and 8, 1888.
- , *from Preliminary to Track.* By M. P. Paret. A paper for young engineers, giving points on the ordinary methods and routine of field and office work on railroad construction. *Engin. News*, Aug. 11, 1888.
- , *Notes on.* By Theo. Low. Give hints which may be of use to young assistant engineers on construction work. *Proc. Engrs. Club, Philadelphia*, Vol. V., pp. 236-242 (February, 1888).
- , *Location.* By Samuel McElroy. Discusses railroad location as one of the most vital questions in railroad construction. *Railroad Gazette*, July 6, 1888.
- , *Field Practice in the West.* By Willard Beahan. A valuable paper on the methods of location from the standpoint of a chief of a locating party. *Jour. Assoc. Engin. Soc.*, June, 1886, Vol. VII., pp. 196-201; *R. R. Gazette*, May 12, 1888; *Sci. Am. Supple.*, June 23, 1888.
- , *with Taper Curves.* By Frank Olmsted. Gives method of locating curves with tapering ends. *Eng. News*, July 21, 1888.
- Railroad and Waterways, Relative Advantages of, in Germany.** By M. Todt. A valuable paper giving statistics relative to the quantities of goods carried in Germany by rail and by water, ratio of tons to population, etc.; also discusses the relative advantages of the railroads and waterways. Translated from the *Bulletin du Ministère des Travaux Publics* for the *Journal of the Royal Statistical Society*, July, 1888; abstracted *Jour. Soc. Arts*, Aug. 31, 1888.
- Rails, Breaking of Iron.** Notes by O. Chanute on the weight of rails and also on the breaking of iron rails. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., pp. 111-117.
- , *Improved Street Car.* Describes the types of rails in use for street car traffic abroad. Illustrated. *Eng. News*, May 12, 1888.

- Rails, Life of.** A report by a committee on the form, weight, manufacture and life of rails. *Trans. Am. Soc. Civ. Engrs.*, Vol. III., pp. 87-110.
- , *Relation of the Section of Rails and Wheels.* The preliminary report of the committee of the American Society of Civil Engineers, to consider the relation to each other of the sections of railroad wheels and rails. *Trans. Am. Soc. Civ. Engrs.*, Vol. XIX. (July, 1888), pp. 1-54; *Engin. News*, Nov. 3 *et seq.*, 1888; abstracted *R. R. Gazette*, Nov. 2, 1888.
- , *Specifications for.* Gives the specifications adopted by Ward & Bros., rail inspectors, Pittsburgh, for steel rails and track fastenings. *R. R. Gazette*, Sept. 7, 1888; *Eng. News*, Sept. 1, 1888.
- , *Specifications for Steel.* By R. W. Hunt, before the American Institute of Mining Engineers. Gives specification for the manufacture of steel rails, embracing the conclusion derived from twenty years' practice in the manufacture of steel. *Eng. and Min. Jour.*, Oct. 27 *et seq.*, 1888; *R. R. Gazette*, Oct. 26, 1888.
- , *Steel.* By T. A. Delano. Gives brief discussion of some of the conditions of manufacture which may greatly influence the life of steel rails. *R. R. Gazette*, Aug. 10, 1888.
- , *Tests Applicable to.* By James E. Howard. Discusses some of the simple methods of testing rails, and the relative behavior under these tests with the more elaborate ones requiring special machinery. *R. R. Gazette*, Sept. 7, 1888.
- , *85-lb. Standard.* Gives drawing with full dimensions of the 85-lb standard-rail of the Pennsylvania Railroad. *R. R. Gazette*, April 6, 1888.
- , *90-lb. Philadelphia & Reading.* Gives drawing, with full dimensions, of the 90-lb. rail being placed on the Philadelphia & Reading Railroad. *R. R. Gazette*, Aug. 24, 1888.
- Rainfall as influenced by forests.** See Forests.
- , *Amount Available for Water Supply.* A paper by Desmond Fitzgerald, with discussion. Gives much observed data in vicinity of Boston. *Jour. New Eng. W. Works Asso.*, September, 1886.
- , *Water Level and, of the Great Lakes.* Gives diagram showing the fluctuations of the water-surface, areas, etc., of the Great Lakes, with comments on the phenomena observed. *Engin. News*, Oct. 6, 1888.
- Refrigerating Machines on Board Ship.** By T. B. Lightfoot. Gives early history of refrigerating machines and then describes in detail special machines for use on board of ships. *Trans. Soc. Engrs.*, 1888, pp. 105-124.
- Refrigerating Machinery, Str. Fifehire.** Illustrated description of the most powerful refrigerating machinery ever put in a ship. It uses compressed air, and is to cool 84,000 cubic feet of space. *Engineer*, Oct. 14, 1887; *Sci. Am. Supple.*, Dec. 3, 1887.
- Reservoir, Athens, Ga.** By C. H. Ledlie, before the Engineers' Club of St. Louis. Gives details of the construction of an earthen dam for the Athens, Ga., water-works. *Jour. Assoc. Eng. Soc.*, April, 1888; *Eng. News*, May 5, 1888.
- , *Bombay, India.* Brief description with plan and section of the John Hay Grant reservoir of the Bombay system. The work comprises a storage basin 350 by 150 by 30, six filters of 16,000 square feet each and a clear well. *Indian Engineering*, Sept. 15, 1888.
- , *Naples, Galleries and Conduit in.* An abstract from *Les Annales des Ponts et Chaussées* describing the reservoirs or galleries excavated in the heart of the mountains for the Naples water supply. *Engin. and Build. Rec.*, Aug. 11, 1888.
- , *Nashville, Tenn.* By H. De B. Parsons. Gives a brief description, with plan and sections of wall, of the new storage reservoir being constructed at Nashville, Tenn. *Engin. News*, June 16, 1888.
- , *New Storage, Grand Junction Company, Earling, Eng.* Gives brief description, with plan, cross sections, elevations, etc., of a new storage reservoir, of a capacity of 51,000,000 gallons, constructed for the Grand Junction Water-Works Company, Earling, England. *Engineer*, Aug. 24, 1888.
- , *Remarkable Breaks in a.* By L. N. Lukens before the Philadelphia Engineers' Club. Gives details of a number of breaks and their repairs in Conshohocken Hill Reservoir. *Proc. Engrs. Club, Philadelphia*, Vol. VI., pp. 147-150 (Dec., 1887); *Engr. News*, Aug. 18, 1888.
- , *Storage.* A description of the building of the embankment of Ashland Basin

- No. 4, Boston Water Supply, by W. F. Learned, together with the methods used for the mixing and handling of concrete. Illustrated. *Jour. New Eng. W. Wks. Assoc.*, December, 1887.
- Reservoir, Vyrnwy, Gauging at.** See River Gauging.
- By Samuel McElroy, before the American Water-Works Association. Contains experience in construction of the Ridgewood reservoir. *Proc. Am. Water-Works Assn.*, Vol. VIII. (1888), pp. 72-77.
- , *Open or Closed?* A paper by E. G. Beach, before the seventh annual meeting of the American Water-Works Association, discussing the question whether storage reservoirs be open or closed. Gives the experience of a number of cities. *Eng. News*, Dec. 3, 1883.
- Resistance, Compensated Standards of.** See Electrical Resistance.
- Retaining Walls.** An attempt to reconcile theory with practice. By Casimer Comstable. *Trans. Am. Soc. C. E.*, Vol. III., pp. 67-75.
- *for Earth.* By Prof. C. E. Greene. A brief graphical determination of pressure at any bed joint, *The Technic*, Univ. of Michigan, 1888.
- By Samuel McElroy. Gives practical notes on the construction of retaining walls. *R. R. Gazette*, Nov. 9, 1888.
- , *Methods of Calculating and Designing.* By C. P. Karr. A series of articles following the methods of Dr. Weyrauch and Prof. Rankine, with additional examples from the French practice. *Building*, Dec. 17, 1887, *et seq.*
- River and Harbor Works in Northern France.** By L. Schrader. Interesting description of the works on the lower Seine and Seine, and of the harbors of Nantes, St. Nazaire, Rouen and Havre. *Zeitschr. d. Oester. Ing.- u. Arch.-Vereins*, 1887, pp. 130-154.
- Rivers and Harbors, Improvements of.** See Public Works.
- River Gauging at Vyrnwy Reservoir.** By J. H. Parkin, before the Students Institution of Civil Engineers. Gives details of the gauging to determine the daily discharge of the Vyrnwy River. *Proc. Inst. C. E.*, Vol. XCII., pp. 353-367.
- River Improvement in Bavaria.** An illustrated article condensed from the *Journal of the Austrian Society of Engineers and Architects*, No. 43, 1887. Shows method of constructing embankment, shore protection and dikes. Gives rule for the proper proportion of depth and width of channel at lowest water line. *Eng. News*, March 17, 1888.
- *on the Atlantic Coast.* By Wm. P. Craighill, before the annual convention of the American Society of Civil Engineers. Gives description of the treatment of several of the tidal rivers of the Atlantic Coast, with comments thereon. *Engin. and Build. Rec.*, Aug. 11, 1888.
- , *River Weaver, Eng.* By J. A. Sauer, before the Society of Arts Canal Conference. Gives a short description of the improvement of the River Weaver, England. *Jour. Soc. Arts*, June 1, 1883.
- Riveted Joints.** Details of tests of 96 specimens of O. H. steel plates, 12 specimens of rivet metal, and of 154 riveted joints made at the Watertown Arsenal in 1885. Report for that year, Ex. Doc., No. 36, 49th Congr., 1st Session.
- Roads, Common, in France.** Gives notes on the administration of the public roads in France. *Engin. and Build. Rec.*, Aug. 18, 1888.
- Road and Drainage Construction in Boston Parks.** Gives brief description of the methods of road construction and drainage adopted in the Boston park system. Illustrated. *Engin. News*, Sept. 15, 1888.
- Road Material of Ohio.** By Ed. Orton. Describes the stone in Ohio available for road-making material. *Rpt. Ohio Soc. Surv. and Engrs.*, 1888, pp. 60-68.
- Road Metal and Paving Setts, Valuation of.** By W. F. K. Stack. Discusses the proper method of testing road-making material, and gives details of tests made on duration by means of a machine. Illustrated. *Engineer*, Aug. 31, 1888.
- Rolling Mill, Universal.** Gives description of Sacks' improved universal rolling mill, adapted to rolling double angle, star, H. T., and similar sections. *Sci. Am. Sup.*, Jan. 7, 1888.
- Rolling Stock.** See Railroads, Cars, Locomotives and Axles.
- Roof Truss.** A brief description with full detailed drawing of main roof trusses of the station of the South Brooklyn Railroad and Terminal Company. The trusses have a span of 147 feet, rise of 30 feet, and 27 feet effective depth. *Engin. and Building, Rec.*, March 17, 1888.

- Roof Truss, Bandora Station.** Brief description with detailed drawing of a roof truss for Bandora Station, India. *Engineer*, Dec. 2, 1887.
- , *Cantilever.* Gives details of a cantilever roof erected by the Berlin Bridge Co. over their girder shop. *Engin. and Build. Rec.*, Aug. 4, 1888.
- , *Depot of the Central Railroad of New Jersey.* Gives plan and elevation of the new depot of Jersey Central Railroad at Communipaw, etc., also half-section showing roof truss, with dimensions. Its span is 142 feet. *Engin. News*, October 6, 1888.
- , *Paris Exhibition.* Description, with elevation and details, of the roof truss over the Fine Arts Court at the Paris Exhibition, 1889. *Engineer*, Sept. 2, 1887; also Sept. 16.
- , *Paris Exhibition.* A two-page plate showing details of roof truss and other iron work of the galleries of miscellaneous exhibits at the Paris Exhibition of 1889. *Engineering*, Dec. 30, 1887.
- , *Phoenix Bridge Co.* Gives short description, with general plans, elevation diagrams and details of the roof trusses of the new girder shop of the Phoenix Bridge Works. *Eng. and Build. Rec.*, April 7, 1888.
- , *Renewal of at King's Cross Terminus, G. N. R.* By R. M. Bancroft before the Society of Engineers. Gives details of the renewal of the roof truss over the departure platform of King's Cross terminus of the Great Northern Railroad. Nine plates. *Trans. Soc. Engrs.*, 1888, pp. 125-145.
- , *Twelfth Regiment Armory, New York.* Brief description, with illustrations, of the riveted arch roof trusses of the armory of the Twelfth Regiment in New York City. *Eng. and Build. Rec.*, Jan. 7, 1888.
- Sanitation of Towns.** By J. Gordon. A presidential address before Society of Municipal and Sanitary Engineers and Surveyors of England. *Sci. Am. Sup.* Nov. 19, 1887.
- Section Lining, Standard.** By T. Van Vleck. Recommends the adoption of standard section to represent the conventional sections of iron, steel, etc., on all engineering drawings. Cuts show the proposed sections. *Eng. News*, Dec. 31, 1887.
- Sewage. Chemical Treatment of Mystic.** By W. T. Learned. Before the Boston Society of Civil Engineers. Gives results of a study of the chemical treatment of Mystic sewage. Precipitant used was crude sulphate of alumina. *Jour. Assoc. Eng. Soc.*, July, 1888, Vol. VII., pp. 244-248.
- , *Deodorization of London.* A report by Sir Henry Roscoe to the Metropolitan Board of Works on the deodorization of London sewage. *Eng. and Build. Rec.*, Sept. 4 et seq., 1888.
- , *Disposal.* By C. A. Allen, before the annual convention of the American Society of Civil Engineers. Gives a brief review of the history of sewage purification in England, and a review of the different methods employed at present. *Trans. Am. Soc. C. E.*, Vol. XVIII., Jan., 1888, pp. 9-23, and a discussion, pp. 24-42.
- , *Disposal at Medfield, Mass.* By Fred Brooks, before the Boston Society of Civil Engineers. Describes the intermittent, downward filtration sewerage system at Medfield, Mass., with map and plans of basins, etc. *19th An. Rep. Mass. Board of Health; Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 235-244; *Engin. and Build. Rec.*, July 16, 1888.
- , *Disposal, European Practice.* By C. H. Swan, before the Boston Society of Civil Engineers. Gives interesting statistics relative to the amount of sewage that may be applied to given areas of land, as shown by experiments at Paris, Berlin, Croydon, etc. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 248-258.
- , *Disposal in Massachusetts.* By F. P. Stearns, before the annual convention of the American Society of Civil Engineers. Gives a statement of the present status of the question in Massachusetts, with a brief reference to the action of the State in the past. *Trans. Am. Soc. C. E.*, Vol. XVIII., January, 1888, pp. 1-7.
- , *Stone and Ault System at Rangoon Town, India.* By H. F. White. A report by order of Chief Engineer of British Burma on the proposed Stone and Ault system of sewage disposal for Rangoon Town. The report is favorable, answering each objection seriatim. *Indian Engineering*, Nov. 5, 1887.
- Sewerage, Acton.** Brief description of the Acton sewerage works, with ground plan. *Engineer*, Sept. 9, 1887.
- , *Assessment of Costs of.* By T. W. Whitlock, before the Connecticut Association of Civil Engineers and Surveyors. Discusses the proper method of assessing

- property for sewerage improvements. *Proc. Conn. Assoc. C. E. and Surv.*, 1888, pp. 57-62.
- Sewerage.** *Fort of Mysore, India.* By Standish Lee. Gives description, with detailed drawing, of sewerage system at the Fort of Mysore, India. *Indian Engin.*, June 30 *et seq.*, 1888.
- , *Frankfort-on-the-Main.* Gives details of the sewerage scheme being carried out at Frankfort-on-the-Main, with drawing showing details. *Engin. and Build. Rec.*, Aug. 11 *et seq.*, 1888.
- , *Henley-on-Thames.* Gives brief description of the Shone system of sewerage at Henley-on-Thames. *Engineer*, Oct. 21, 1887.
- , *Henley-on-Thames.* A short description of the Shone system as applied at Henley-on-Thames, England, to an area of 175 acres, with 4,000 population, and a flow of 1,800 galls. per diem. Cost, \$86,400. *Engin. and Build. Rec.*, Feb. 18, 1888.
- , *Luton.* Brief description of the Luton, Eng., sewerage farm. *Engineer*, Nov. 18, 1887.
- , *Southampton, Eng.* An abstract of a paper by W. B. G. Bennett, before the Institution of Civil Engineers. Gives a description and cost of operation of the sewage clarification and house-refuse disposal works at Southampton, Eng., with plans and sections. *Engr. and Build. Rec.*, April 23, 1888.
- , *Shone Hydro-Pneumatic System.* By Edwin Ault, before the Society of Engineers. Gives full description of the Shone hydro-pneumatic system of sewerage, with details of the works at Eastborne, House of Parliament and Henley-on-Thames. *Trans. Soc. Engrs.*, 1888, pp. 68-105.
- , *Wednesbury.* Gives brief description of the works at Wednesbury. The sewage is treated with sulphate of alumina and lime. *Engineer*, Dec. 16, 1887.
- Sewers.** Gives the decision in the case of the New London sewer assessments. The assessments hold good. *Engr. and Build. Rec.*, March 31, 1888.
- , *Construction of, in Madras, India.* By Hormusji Nowrosji. Records some of the construction details of sewers of Black Town, Madras, India. The three sewers have a total length of $5\frac{1}{4}$ miles, varying in diameter from 12 to 30 in. It is on the separate system. *Indian Engineering*, March 31, 1888.
- , *Discharge of Circular and Egg-shaped.* By W. T. Olive, before the Institution of Civil Engineers. Gives diagrams, based on Beardman's formulas for finding the discharge of circular and egg-shaped sewers. *Proc. Inst. of C. E.*, Vol. XCIII., pp. 333-339.
- , *Flow of Air in.* Gives details of experiments by W. E. McClintock on the flow of air in pipe sewers, and its effect on traps at the foot of soil-pipe. *Engr. and Build. Record*, Feb. 11, 1888.
- , *Memphis.* By Rudolph Hering. Gives conclusions arrived at from a recent inspection of the Memphis sewerage system. *San. Engr.*, Nov. 24, 1887.
- Screw Threads, New System of.** Recites objections to systems in use, and proposes a new system giving an increase of strength of 17 per cent. over the Sellers thread. By John L. Gill, Jr., Phila. *Journal Franklin Institute*, March, 1888.
- Shafts, Propeller, for Marine Engines.** Treats of the material from which they are manufactured, investigates the strains and proper proportions. *Mech. World* Dec. 17, 1887.
- Shaft Sinking through Loose Material.** By A. McC. Parker. Gives description with details of the method employed to sink a shaft at the "Tilly Foster" mines *School of Mines Quar.*, Oct., 1887; *Engr. News*, Dec. 3, 1887.
- Signals, Interlocking.** See Railroads.
- Ship Railway, Venetian.** By E. L. Corthell, before the Philadelphia Engineers' Club. Gives an interesting sketch of ship railroad project carried out in Venice in the 15th century. *Proc. Engrs. Club, Phila.*, Dec., 1887, Vol. VI., pp. 153-165.
- Ships, Tonnage of.** A good review of the use of the terms ton and tonnage as employed in maritime commercial transactions. *Engineer*, Dec. 30, 1887.
- Ship Transfer. Present Aspect of the Problem of American Inter-Oceanic Ship Transfer.** Read before the Engineers' Club of St. Louis, March 2, 1887, by Robert Moore. A complete and interesting exposition of the subject. *Jour. Assoc. of Engr. Soc.*, February, 1888.
- , By E. L. Corthell. A review of the above paper, and a reply to the review by Robert Moore. *Jour. Assoc. of Engr. Soc.*, May, 1888.
- Sinking Funds. Formulae Derived.** *Jour. New Eng. W. Wks. Assoc.*, June, 1887.

- Siphon, Automatic Intermittent.** Gives a description of a self-priming siphon for sanitary or manufacturing purposes where a periodical flush is required. *Sci. Am. Supple.*, March 31, 1888.
- Skew Arch.** See Arches.
- Slide Rule.** By E. A. Gieseler. Gives description and rules for using this valuable instrument. *R. R. Gazette*, March 9, 1888.
- Snow Sheds, Canadian Pacific Railroad.** Gives description with drawings of the different forms of snow-sheds in use on the Canadian Pacific Railroad. *Engin. News*, Jan. 21, 1883.
- Standard of Length, Wave Length of Sodium as a.** By Prof. A. A. Michelson and E. W. Morly, before the Civil Engineers' Club of Cleveland. Gives a method for making the wave length of sodium light the actual and practical standard of length. *Jour. Assoc. of Engin. Soc.*, May, 1888.
- Steam, Effect of Circulation on.** By G. H. Barrus, before the American Society of Mechanical Engineers. Gives experience in the effect of circulation in steam boilers on the quality of the steam. *Am. Engr.*, May 9, 1888.
- , *Efficiency of High Pressure.* By W. W. Beaumont, before the British Association. Object of paper is to show that Carnot's theorem is limited in its application to the steam engine, and that high pressure steam must theoretically, as well as practically, be more efficient than low pressure. *R. R. Gazette*, Nov. 2, 1888.
- , *Generation of.* By G. H. Babcock. A Sibley College lecture. Treats of the generation of steam in tubular boilers. Illustrates and describes the different boilers with furnaces for burning coal, wood, gas, bagasse, etc. *Sci. Am. Sup.*, Dec. 17 and 24, 1887.
- Steam Engine, Contribution to a Rational Theory of the.** A series of articles intended to supply a description of the phenomena attending the performance of work in a steam engine and certain deductions logically following on the phenomena. *Engineer*, July 6, et seq., 1888.
- , *A New.* By H. Turner. Gives a description of a new form, tandem compound, of steam engine. *Engineer*, July 20, 1888.
- Steam Engineering, Introduction to the Study of.** By R. H. Buel. A series of articles for practical men with a limited education. *Am. Engineer*, May 30 et seq., 1888.
- , *River Practice in the West.* By J. M. Sweeney, before the Nashville meeting of the American Society of Mechanical Engineers. *Am. Engineer*, June 13, 1888.
- Steam Heating.** See Heating Cities by Steam.
- , See Heating.
- , See Car Heating.
- Steam Plant, Station J, New York Steam Co.** Gives a full description of the plant of the New York Steam Company at Station J. Shows plans of building, pipe arrangements, etc. *Engin. and Build. Rec.*, April 7, 1888.
- Steamer, Stern-Wheel.** A description of a stern-wheel steamer, 120 ft. long by 24 ft. 6 in. beam, recently constructed for the navigation of Maddolena River, South America. Plan and elevation. *Engineer*, Sept. 30, 1887; *Sci. Am. Sup.*, Nov. 12, 1887.
- Steel, Basic Siemens Process.** A paper by F. W. Harboard, before the Iron and Steel Works Managers' Institute, giving a description of the Basic-Siemens process of making steel. *Mech. World*, Dec. 31, 1887; *Engineering*, Dec. 16, 1887; *Am. Manuf.*, Jan. 6, 1888. A description of the Batho furnace to employ this process will be found in the same number of *Am. Manuf.*
- , *Bessemer, Modifications of the Process.* Abstract of a lecture before the Franklin Institute, Jan. 3, 1887, by C. Hanford Henderson. Treats especially of the Clapp-Griffiths and the Thomas and Gilchrist methods. *Journal of the Franklin Institute*, June, 1887, Vol. CXIII., No. 738.
- , *Bridge, Discussion on.* Gives a discussion on bridge steel that took place at an Edinburgh meeting of the Iron and Steel Institute. *R. R. Gazette*, Sept. 14, 1888.
- , *Compressive Strength of Iron and.* By C. A. Marshall. Gives results of a large number of tests made to discover the relation which compressive strength

bears to tensile strength. *Trans. Am. Soc. Civ. Engrs.*, Vol. XVII., pp. 53-110 (August, 1887).

Steel, as flooring. See Flooring.

— *Direct from the Ore.* By F. L. Garrison, before the Boston meeting of Mining Engineers. Gives the results of investigation of the attempts to produce steel direct from the ores. Describes in detail the development of Hasagafoel's improved high bloomery (a modification of the old Stackofen process) for the production of iron and steel direct from ores. Illustrated. *Am. Manuf.*, April 6, 1888.

— *Effect of Temperature upon Structural Iron and Steel.* By Jos. Ramsey before the Engineers' Society of Western Pennsylvania. Gives the results of some tests and investigations. *Eng. News*, Dec. 3, 1887.

— *Fifteen Years of Open-Hearth Experience.* By W. E. Kock before the Engineers' Society of Western Pennsylvania. Traces the development of the open-hearth process, and gives much interesting information concerning the use and working of steel. Abstracted *Engin. and Build. Rec.*, May 19, 1888, and *Engr. News*, June 9, 1888; *Am. Engr.*, June 27, 1888; *R. R. Gazette*, Aug. 17, 1888.

— *Improvements in Open-Hearth Practice.* By A. E. Hunt, before the Boston meeting of the American Institute of Mining Engineers. Gives a good description of the process of making wrought iron direct from the ore employed by the Carbon Iron Company at Pittsburgh. *Eng. News*, March 24, 1888.

— *Influence of Copper on Tensile Strength.* A paper prepared by E. J. Ball and A. Wingham for the Iron and Steel Institute. Gives results of experiments made to ascertain the effect of copper on the tensile strength of steel and iron. It appears to render them extremely hard. *Amer. Manufacturer*, Sept. 28, 1888.

— *Its Properties, Its Use in Structures and Heavy Guns.* By Wm. Metcalf, before the American Society of Civil Engineers. A valuable contribution on steel, and a plea for the Rodman gun. Discussion covering 90 pages. *Trans. Am. Soc. C. E.*, Vol. XVI., pp. 283-389, June, 1887. Abstracted in *R. R. Gazette*, March 18, 1887; *R. R. and Eng. Jour.*, April, 1887; *Am. Engineer*, April 6 and 13, 1887.

— *Manganese.* By R. A. Hadfield, before the Institution of Civil Engineers. Two papers, "Manganese in its Application to Metallurgy," and "Some Newly Discovered Properties of Iron and Manganese." Iron with from 2.75 to 7 per cent. of manganese is very brittle; between 7 and 20 per cent. of manganese give a very strong and tough material, specimens of which broke with a tensile strain of 65 tons and showed an elongation of 50 per cent. *Proc. Inst. C. E.*, Vol. XCIII., pp. 1-108; abstract *Engineering*, March 9, 1888; *R. R. Gazette*, March 30 and Sept. 7, 1888; *Sci. Am. Supple.*, April 7, 1888; *Mech. World*, March 10, 1888; *Engineer*, March 16, 1888; *Am. Manuf.*, April 6, 1888; *T. J. and Elec. Rev.*, Aug. 10, 1888; *Master Mechanic*, October, 1888.

— *Plate Building.* See Buildings.

— *Open-Hearth for Boilermaking.* By H. Goodall, before the Institution of Civil Engineers. The paper gives the experience of the author in the use of open-hearth steel for boilermaking since 1875, and describes numerous experiments to ascertain the cause of difficulties met with in working the plates. *Proc. Inst. C. E.*, Vol. XCII., pp. 2-72; abstract in *Engineering*, Jan. 13, 1888; *Mech. World*, Jan. 24, 1888.

— *Results from Tests made shortly after Rolling.* By E. C. Felton, before the Philadelphia meeting of the American Society of Mechanical Engineers. Gives notes on the results of a large number of tests made to determine the effects of tests of steel shortly after the rolling. *Trans. Am. Soc. Mech. Engrs.*, Vol. IX. (1888), pp. 38-50.

— *Tests of the New Direct Process Open Hearth.* Gives results of tests made by G. H. Thomson of the new direct process open-hearth steel, of the Carbon Iron Co. made at the shops of the Union Bridge Co. It stood severe tests, and bids fair to become an important production. *Engin. News*, Jan. 21, 1888.

— *Use of Aluminum Alloys in Making.* A discussion by the Engineers' Society of Western Pennsylvania on the use of aluminum alloys in steel making. *R. R. Gazette*, May 11, 1888.

Steel Cables. See Cables.

Steel Tapes, Use of, in Surveying. By J. B. Johnson, before the Ohio Society of Surveyors and Civil Engineers. Discusses the different errors and their effects; the limits of error; standardizing tapes, etc. *Engr. News*, March 3 and 10, 1888.

- Steelworks, Terni, Machinery for the.** By H. Savage, before the Institute of Civil Engineers. Gives description of the plant at the new Terni, Italy, steelworks. *Proc. Inst. C. E.*, Vol. XCIII., pp. 390-404.
- Stand Pipes.** See Water Supply.
- Stone Arches.** See Arches.
- Storage Batteries for Electric Locomotion.** By A. Reckenzaun. A paper read before the Electric Light Association. Gives historical facts and working figures of expense, etc. *Sci. Am. Supple.*, Nov. 5 and 19, Dec. 24, 1887.
- See Batteries.
- Strains in a Cast-Iron Disk.** By G. Leverich before the American Society of Civil Engineers. Gives details and results of an investigation to determine the strains in a cast-iron hollow disk cut from the sinking head of a casting of a Rodman gun. *Trans. Am. Soc. C. E.*, Vol. XVIII., Feb., 1888, pp. 43-50.
- in Highway Bridges. See Bridges.
- in Iron and Steel, Permissible. *Annales des P. and C.*, December, 1887.
- Street Railroads.** An illustrated description of the Mekarski compressed air car, several of which are now working on a London road. *Engineering*, March 23, 1888.
- See Electric Railroads and Elevated Railroads.
- Strength of Materials. Z-Iron Columns.** By C. F. Strobel before the American Society of Civil Engineers. Gives details of the tests of 15 columns of Z-iron. Abstracted *R. R. Gazette*, July 13, 1888.
- Stress, Elevation of the Limit of.** A paper describing a series of experiments to determine facts in regard to the operation of the law called the elevation of the limit of stress, with miscellaneous experiments to determine physical phenomena accompanying rapid alternation of strain and rest. *Report of U. S. Board of Testing, etc.*, Vol. 1, 1881, pp. 107-121.
- Struts, Stiffness of.** Gives results of experiments made at Mason College to investigate the influences of variation of load, of length, and of eccentricity of thrust from centre of end section. *Engineer*, Jan. 6, 1888.
- , Working Strength and Stiffness. By Prof. W. H. Smith. *Engineer*, Oct. 14 and 28, 1887.
- Subway, Proposed New York.** Gives substance of a report to the Commissioner of Public Works of New York as to feasibility and cost of removal to subways under sidewalks of all pipes, conduits, wires, etc., now buried under street pavements. *Eng. and Build. Rec.*, Aug. 4, 1888.
- Surveys, Exterior Boundary of Townships.** By Z. A. Enos. Discusses whether the exterior boundary line of a township, as first run or as modified by subdivisional lines and corners, is to be regarded the true boundary line. *Rep. Ill. Soc. Engrs. & Surv.*, 1888, pp. 90-101.
- , New Jersey State. An extract from the Report of the State Survey of New Jersey, describing the work done and the manner of preparing the results for publication. *Eng. News*, April 14, 1888.
- , Outfit for Railroad. By Benj. Thompson. Gives description of the outfit of a railroad surveying party, and tells how the work was done. *Rept. Ohio Soc. Surv. and Engrs.*, 1888, pp. 237-244.
- , State. By Charles C. Brown. Discusses the need of state surveys and gives the cost of such work in different states. *Jour. Assoc. of Eng. Soc.*, May, 1888.
- See Railroad Location.
- Surveying, Plane Table.** By Josiah Pierce, before the Institution of Civil Engineers. Discusses the economic use of the plane table in topographical surveying, with discussion. *Proc. Inst. C. E.*, Vol. XCII., pp. 187-256.
- , Use of Stadia in Railroad. By J. B. Johnson. A series of articles showing how the stadia rods may be used with advantage in preliminary railroad surveys. *R. R. Gazette*, Feb. 3 et seq., 1888.
- Surveying and Geodesy, Literature of,** for the year 1886, by R. Gerke. A complete list of books and papers on these subjects for 1886. Valuable for those desiring to keep posted on this subject. *Zeitschr. f. Vermessungswesen*, 1887, pp. 475-502, 514-519.
- Switch, Standard Point B. & A. R. R.** By C. E. Alger. Gives plan and details of the point switch in use as the standard of the Boston & Albany Railroad. *R. R. Gazette*, March 2, 1888.
- See Railroads.

- Switchback.** *Stampede Pass, N. P. R. R.* A description with plans and profiles of the temporary switchback of the Northern Pacific Railroad over the Cascade Mountains at Stampede Pass. *R. R. Gaz.*, Dec. 23, 1887. For details of method of running trains over this switchback see *R. R. Gaz.*, Jan. 13, 1888.
- , By H. S. Huson. Gives reasons for its construction, and details of location, track and locomotives, etc. *R. R. Gazette*, Feb. 3, 1888.
- Telescopes.** *for Stellar Photography.* By A. Grubb, before the Society of Arts. Describes the telescopes to be used in the proposed international survey of the heavens. *Jour. Soc. Arts.*, April 20, 1888.
- , *Great, of the World.* By J. K. Rees, before the New York Academy of Science. Gives a popular account of the great telescopes of the world, and discusses their construction, powers and future prospects. *Sci. Am. Supple.*, March 3, 1888.
- Toredo Navalis, or Ship Worm.** By G. W. R. Bayley. Gives the experience with the teredo navalis on the bridge piling and foundation of a railroad from New Orleans to Mobile. *Trans. Am. Soc. C. E.*, Vol. III., pp. 155-171.
- Testing Machine, Cement.** Drawings of the cement testing machine in use at Poughkeepsie bridge. *Engr. and Build. Rec.*, Jan. 21, 1888.
- Testing, Material.** Gives the tests that material supplied for locomotives on the Missouri Pacific Railroad must stand. *Nat. Car and Loco. Builder*, December, 1887.
- , *Strength of Engineering Material.* By Prof. J. B. Johnson. Gives summary of the present state of knowledge relating to certain materials and indicates how tests may be made useful in designing. *Jour. Asso. Eng. Soc.*, Vol. VII., pp. 92-101, March, 1888.
- Tests.** *Alloys.* See Alloys.
- , *Impact on Iron.* A paper describing a series of impact tests upon various irons, with illustrated description of the hammer and method of use; tabulated details of tests and physical phenomena observed during the work. *Report of Board of U. S. Testing, etc.*, 1881, Vol. I., pp. 122-146.
- , *of Wood Treatment.* Gives details of tests to ascertain the relative life and value of wood treated with various antiseptics and untreated timber in resisting the ravages of the teredo. *Engin. News*, Sept. 1, 1888.
- , *Steam. Report of the Steam Engine Tests* made at the Franklin Institute Electrical Exhibition at Philadelphia in 1884. Very complete tests of Porter-Allen, Southwark and Buckeye engines. *Journal of the Franklin Institute*, February, 1886, Vol. CXXI., No. 722.
- , See Governor, the Ball.
- Test Pieces, Incorrectly Proportioned.** A paper showing the errors in estimating results of tension tests due to the use of incorrectly proportioned test pieces. *Rep. U. S. Board of Testing*, Vol. I., pp. 91-104.
- , *Forms and Proportions of.* A paper showing by experiment the correct form and proportions of test pieces to procure correctly the tenacity, elastic limit, etc., of various metals. *Report of U. S. Board on Testing, etc.*, 1881, Vol. I., pp. 91-105.
- Thermo-Magnetic Generator and Motor.** Gives an illustrated description of the Menges generator and motor, designed for the more direct conversion of heat into electricity. *Sci. Am. Supple.*, Feb. 18, 1888.
- Ties, Steel.** See Railroads.
- , *Metallic.* Gives figures showing the cost of maintenance of track laid with metallic ties. *R. R. Gaz.*, Dec. 16, 1887.
- Timber, Creosoting in New Zealand.** By Wm. Sharp, before the Institute of Civil Engineers. Gives description of the first plant erected in Australasian colonies for creosoting timber; also gives specimens of 50 creosoted sleepers. *Proc. Inst. C. E.*, Vol. XCIII., pp. 408-420.
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- , *Its Diseases.* A paper by Marshall Ward giving a full discussion of the growth of timber and its diseases, with an investigation of the causes of decay. *Sci. Am. Supple.*, March 17 et seq, 1888.

- Torpedo-Boat, "Fatum."** A brief description of the station torpedo boat "Fatum," with two-page plate showing plans, elevations and cross-sections. *Engineering*, Jan. 20, 1888.
- Torpedo, Howell's.** Gives a full comparison of the Howell with the Whitehead and Brennan torpedo. Shows the Howell to be the best. *Engineering*, Jan. 20, 1888.
- Tow-Boat Operated by the Current to Tow Vessels Up-Stream.** *Annales des P. and C.*, November, 1887.
- Town Refuse, Destruction of.** By Thomas Codrington. Gives a report on the different methods in use for destroying town refuse. Contains large amount of data relating to refuse. Abstracted *Eng. and Build. Record*, Sept. 15, 1888.
- Track Maintenance.** See Railroads.
- Tramway, Compressed Air.** A review of the Vincennes-Ville Evrard compressed air tramway, which has been in operation for nine years. Illustrated. *Sci. Am. Supple.*, March 17, 1888.
- , *Electric, Bessbrook and Newry.* By E. Hopkinson, before the Institute of Civil Engineers. Describes the construction and discusses the working of the Bessbrook and Newry electrical tramway, designed for freight and passenger traffic. Gives full details. Experiments show the electrical efficiency to be 72 per cent. *Engineer*, Dec. 16; *Engineering*, Dec. 9, 1887. Abstract in *R. R. Gazette*, Feb. 24, 1888.
- Train Service, American and Foreign.** By A. T. Hadley. Gives a comparison of the train service in the different countries. Shows the average frequency of trains and the proportion between train service and population. *R. R. Gaz.*, Nov. 25, 1887.
- Transit Notes, Best Method of Keeping.** Gives a number of articles on the best method of keeping transit notes of curves. *Engin. News*, Sept. 22, *et seq.*
- Transformers, Alternate Current.** By Gisbert Kapp, before the Society of Telegraph Engineers and Electricians. Gives a full treatment of alternate current transformers, with special reference of the proportion of iron and copper. A valuable paper. *Tel. Jour. and Elec. Rev.*, Feb. 18 *et seq.* 1888; *Engineer*, Feb. 10 *et seq.*; *Engineering*, Feb. 16 *et seq.*, 1888; *Electrical World*, March 17, 1888.
- Transmission of Power, Compressed Air.** By Prof. W. C. Unwin. States in a simple form the laws governing the transmission of power by compressed air. *Proc. Inst. C. E.*, Vol. XCIII., pp. 421-436.
- , *Electrical.* By Prof. Ayrton, before the Bath meeting of the British Association. Discusses the advantages of electrical transmission of power, and tells what is being done. *T. J. and Elec. Rev.*, Sept. 21, 1888; *Am. Eng.*, Oct. 3 *et seq.*, 1888.
- , *Electrical.* Gives details of the experiments made in November, 1886, at the Oerlikon Works at Zurich. The dynamos were about 50 horse-power, and were to be used over a distance of five miles. Illustrated. *Engineer*, April 13, 1888.
- , *Electrical.* Gives results of the electrical transmission of work from Kriegstetten to Solothurn. Is described by Prof. H. F. Weber, Reporter to the Commission of Measurement. *Tel. Jour. and Elec. Rev.*, Feb. 17, *et seq.*, 1888; from the *Schwartz Bauzeitung*, Vol. XI., Nos. 1 and 2; condensed account in *Sci. Am. Supple.*, March 3, 1888.
- , *Electrical.* Gives further tests of the electrical transmission of a water-power of 50-horse maximum by four Brown dynamos at Kriegstetten, Switzerland. *Engineering*, April 20, 1888.
- , *Hydraulic.* See Power.
- , Gives illustrated description of the method of rope transmission adopted in the boiler shops of the Southern Railroad of France. *R. R. Gaz.*, Jan. 13, 1888.
- Trestles, Cluster Bent.** By J. A. Hanlon. Gives details of a high trestle near Flushing, O., constructed on the cluster bent plan; shows plan and cross-sections. *Engr. News*, Dec. 31, 1887.
- , *Standard Plans.* Give plans and details of the standard pile trestle in use on the Chicago, Burlington & Northern Railroad. *Engr. News*, June 9, 1888.
- Trestle Work, Special Features in Wooden.** Discusses the use of mortise and tenon-cap bolting, end bearings, etc. *Engin. News*, July 21, 1888.
- Triangulation.** The field operations of the primary triangulation of the Prussian survey. By Erfurth. General description, outfit, signals. *Zeitschr. f. Vermessungswesen*, 1887, pp. 377-383, 421-437.

- Tunnel, Alignment of Nepean, N. S. W.** By T. W. Keele before the Institution of Civil Engineers. Gives details of the alignment of the Nepean Tunnel for the Sidney water supply, New South Wales. Length of tunnel, 23,507 ft., $7\frac{1}{2}$ ft. high, and $9\frac{1}{2}$ ft. wide. Error in alignment for 4,341 ft. was $\frac{5}{8}$ in., and in levels, $\frac{1}{4}$ in. *Proc. Inst. C. E.*, Vol. XCII., pp. 259-267.
- , **Coosa Mountain.** Gives brief description, with section, of the tunnel on the Columbus & Western R. R., near Birmingham, Ala. Length, 2,434 ft.; width, 16 ft., with centre height of $21\frac{1}{2}$ ft. *R. R. Gazette*, Aug. 3, 1888.
- Tunnel, New Croton Aqueduct.** Gives details of the meeting of the headings of the tunnel. *San Engr.*, Nov. 26, 1887.
- , **Proposed Simplon.** Gives brief review of the history and merits of the proposed Simplon Tunnel between Switzerland and Italy. Illustrated with profiles and plan. *R. R. Gazette*, Aug. 17, 1888.
- , **Vosburg, Construction of the.** A pamphlet of 56 pages, with plates showing sections of the tunnel at various stages, systems of timbering, drilling, firing, etc., and letter-press giving details of construction, cost, etc. Address the author, L. Von Rosenburgh, 35 Broadway, New York. Abstracted in *Engineering*, April 6, 1888.
- Tunnels, Bottom or Top Heading in.** By C. L. Kalmbach. Discusses the use of top heading and advocates the use of bottom heading. Illustrated. *Engr. News*, March 24, 1888.
- Tubes. Rolling Seamless Tubes from Solid Ingots.** By Frederic Siemens before the Bath Meeting of the British Association for the Advancement of Science. Describes the Mannesmann process of rolling seamless steel tubes from a solid ingot. *Amer. Eng.*, Oct. 10, 1888.
- , **Seamless Tubes made from Solid Blanks.** A novel method of making a tube from a solid ingot by passing it between rolls described and illustrated. *American Machinist*, Oct. 15, 1887; *Sci. Am. Supple.*, March 24, 1888; *R. R. Gazette*, Oct. 17, 1887, and *Engineer*, Nov. 11, 1887.
- Turbine, Compound Steam.** Gives a description and discussion of a motor composed of a series of 45 turbines acted upon by a current of steam. *Sci. Am. Supple.*, Feb. 18, 1888.
- Turbines, Terni Steel Works.** Gives illustrated description of turbines at the steel works of Terni, Italy. *Engineer*, Sept. 23, 1887.
- Turn-Tables. Indian Railroads.** Gives drawings, in detail, with dimensions for the turn-tables to be used on the Indian State Railroads. *Engineer*, Oct. 23, 1887.
- Viaduct, Approach and Terminus, Montreal.** A brief illustrated description of the masonry approach and terminus of the Canadian Pacific Railroad at Montreal. Also shows the cost of maintaining an iron and masonry viaduct. *Engin. News*, March 3, 1888.
- , **New Tay.** By S. S. Kelsey, before the Institution of Mechanical Engineers. Gives full description of the new Tay viaduct and some of the methods employed in its erection. *Engineer*, Sept. 2, 1887.
- , **Stanucca, N. Y., L. E. & W. R. R.** Gives details of the Stanucca viaduct on the New York, Lake Erie & Western Railroad, taken from an old letter book of its designer, Mr. J. W. Adams. *Engin. News*, Sept. 1, 1888.
- Voltmeters, Portable, Ayton and Perry's.** These instruments are an improvement upon the Cardew voltmeters, and depend upon the expansion of a fine wire due to the heating effect of a current. *Electrical World*, Jan. 28, 1888.
- War Ships, American.** By W. John, before the Institution of Naval Architects. Gives description of a competitive design which was accepted by the U. S. Naval Department. *Engineering*, March 30, 1888.
- Washouts, Their Prevention and Treatment.** By W. B. Parsons. Shows what can be done to prevent washouts, what to save damage during their occurrence, and especially what is to be done after they have taken place. *R. R. Gazette*, April 20, 1888.
- Watches, Magnetism in.** By C. K. Giles, before the Alexandria Bay meeting of the American Railway Master Mechanics' Association. Gives the results of four years investigation of the effect of magnetism in watches. *Master Mechanic*, Sept., 1888.
- , **Paillard's Non-Magnetic Compensating Balances and Hair-Springs for.** By Prof. Edwin J. Houston. Describes Paillard's non-magnetic watches, gives com-

- position of alloys used, and results of careful tests of the watches. A distinct advance in the construction of accurate timepieces. *Journal of Franklin Institute*, March, 1888.
- Watches.** *Protection of Watches against Magnetism.* Also, a convenient method of demagnetizing. Paper by Dr. P. Lange, read before the National Electric Light Association, Pittsburgh. *Electrical Engineer*, March, 1888; *Electrical World*, March 3, 1888.
- Water Aeration and Filtration.** Paper by Charles B. Brush, with discussion. Many new and pertinent facts presented, especially in the discussion by Dr. Leeds. *Jour. New Eng. W. Works Assn.*, September, 1887.
- Water Analysis for Railroads.** A paper by George Gibbs before January meeting Western Railroad Club. Discusses the subject from a practical standpoint and gives the experience of the C. M. & St. P. R. R. Gives method of gathering data, results of analysis, etc. *Master Mechanic*, February, 1888.
- , *Mississippi River.* Abstract from the report of Dr. Charles Smart, giving the result of a series of analyses made for the State Board of Health of Minnesota of the waters of the Mississippi River and some of its tributaries. *Eng. and Build. Record*.
- Water, Action of Boston, on Service Pipes.** By Wm. R. Nichols and L. K. Russell. Gives details of experiments made to discover the amount of zinc taken up from galvanized iron water pipes. Results show that the zinc coating is slowly but continuously dissolved. *Jour. Assoc. Engin. Soc.*, January, 1888, pp. 12-14; *Engin. News*, February, 1888; *Sci. Am. Supple.*, March 3, 1888; *Eng. and Build. Rec.*, March 31, 1888; Abstracted *Proc. Inst. C. E.*, Vol. XCIII, p. 480.
- , *Consumption and Capacity* in thirty cities and towns for the year 1886. *Jour. New Eng. Water-Works Assoc.* for March, 1888.
- , *Clark's Process of Softening.* An editorial giving a summary of a long correspondence on the softening of water by the Clark process. *Engineer*, Oct. 21, 1887.
- , *Discharge of.* See Flow of Water.
- , *in "Great Ponds." To Whom Does it Belong?* The question argued in favor of the public, as against the riparian owners below. *Jour. New England Water-Works Assn.*, Dec., 1886.
- , *in Japan. A Description of Japanese Water Supply Systems.* By Prof. W. S. Chaplin. *Jour. New England Water-Works Assn.*, Dec., 1886.
- , *Pollution of Air and.* By A. E. Fletcher, before the Society of Arts on the present state of the law concerning the pollution of air and water. Shows what the law has done, and what is still hoped for from its further action. *Jour. Soc. Arts*, April 13, 1888.
- , *Softening.* Two articles, showing how to accurately determine the degree of hardness of water, and by what means it has been proposed to artificially soften it for domestic use. Discusses the Porter-Clark, Stanhope Company's and the Anti-Calcaire processes. *Engineer*, Feb. 3 and 10, 1888.
- , *The Odor and Color of Surface Waters.* A most excellent paper and valuable discussion before the New England Water-Works Association. By Prof. Thos. M. Drown. Gives methods of determination and results of the official examination of the potable waters of Massachusetts, the whole covering 27 pages in the *Jour. New Eng. W. Wks. Assn.*, March, 1888.
- Water Gas, as applied to Metallurgical Processes.** By A. Wilson, before the Iron and Steel Institute. Describes the modifications of Lowe and Strong's process developed at Essen, and its application to heating purposes and steel melting at Wilkowitz, Terni, etc. *Am. Manuf.*, June 8, 1888.
- Water Hammer, a Discussion,** giving the experience of water-works superintendents. *Jour. New Eng. W. Works Assn.*, Sept., 1886.
- Water Mains, Cleansing.** By J. H. H. Swiney, before the Institution of Civil Engineers. Gives details of the cleansing of the water mains at Omagh. The pipe was coated with about one inch of peat. Scrapers were sent through the pipe. *Engineering*, April 13, 1888.
- , *Detection of Leaks in.* By Joseph Francis. *Engineer*, July 13, 1888.
- , *Draining and Filling.* By S. B. Russell, before the Engineers' Club of St. Louis. Discusses the precautions that should be taken in draining and filling

- water-mains. *Jour. Assoc. Engr. Soc.*, Vol. VI., 1887, pp. 298-305; *San. Engr.*, Dec. 24, 1887.
- Water Meters.** A discussion covering 11 pages in the *Jour. New Eng. W. Works Association* for September, 1886.
- Water-Meter, Venturi.** By Clemens Herschel, before the American Society of Civil Engineers, giving details of experiments made with a meter, embodying the property of Venturi tubes, applied to pipes from one to nine feet in diameter. Eight plates. *Trans. Am. Soc. C. E.*, Vol. XVII. (November, 1887), pp. 228-258; abstracted *Prac. Inst. C. E.*, Vol. XCIII., pp. 515-516; abstracted in *San. Engr.*, Dec. 24, 1887.
- Water-Meters. Recent Tests at Boston.** By L. F. Ries, before the Boston Society of Civil Engineers. Gives details of the methods and apparatus used in "making a full test and report" upon the merits of water-meters for the Boston Water Board. *Jour. Assoc. Engrs. Soc.*, August, 1888, Vol. VII., pp. 285-297.
- *System of, Providence, R. I.* By E. B., Weston, before the Boston Society of Civil Engineers. Gives details of the management of the water meter system at Providence, R. I., where 58 per cent. of the consumers have meters. *Jour. Assoc. of Engrs. Soc.*, August, 1888, Vol. VII., pp. 297-304; *Engr. News*, Aug. 11, 1888.
- Water Motor,** which works automatically in a supply pipe to a reservoir, with 5 pounds pressure, whether towards or from the reservoir, pumping a percentage of the water passed to a level 60 feet higher. Has been in successful operation at Burlington, Vt., for six years. Described by F. H. Parker, Superintendent of Water-Works. Illustrated. *Jour. New England Water-Works Assn.*, September, 1887.
- Water-Pipes.** By A. H. Howland. Treats of the different kinds of pipes, their qualities and availabilities. *Proc. Phila. Engrs. Club*, Vol. VI., p. 55; *Am. Engr.*, April 20, 1887; *Sci. Am. Sup.*, Feb. 12 and Nov. 5, 1887.
- , *Cast-Iron.* Gives a table of dimensions of cast-iron water-pipes as derived from the practice of an experienced engineer. *Mech. World*, Sept. 22, 1888.
- , *Dimensions of.* By J. E. Codman, before the Philadelphia Engineers' Club. Discusses the diameter of pipe-flanges, diameter of bolt circle, size and number of bolts and thickness of cast-iron pipe. Gives diagram to show graphically the above points. *Proc. Engrs. Club, Phila.*, Dec. 1887, Vol. VI., pp. 150-152.
- Water Rates, Uniform Classification of.** Report of a special committee and discussion of same. *Jour. New England Water-Works Assn.*, September, 1887.
- Water Supply, Aeration of.** By S. E. Babcock, before the New England Water-Works Association. Describes the method of aeration adopted at Little Falls, N. Y. It consists of a series of mains constructed in an open paved channel. *Engin. and Build. Rec.*, Jan. 30, 1888; *Sci. Am. Suppl.*, July 14, 1888.
- , *Arrangement of Piping for.* An analysis and description of the piping usually required for water-works pumping stations. By Charles H. Fitch, D. E. *Mechanics*, April.
- , *Biological Examination of a.* By W. T. Sedgwick, before the New England Water-Works Association. Discusses the methods, results and their interpreting of biological examination of water. Discussion *N. Eng. W. Works Assoc.*, June, 1888, Vol. II., pp. 7-26.
- , *Available Rainfall.* See Rainfall.
- , *Capacity of Drainage Ground in Time of Drought.* A study of the capacity of the Sudbury and Lake Cochituate water-sheds in time of drought. By Desmond FitzGerald. Reprinted in *Jour. New Eng. W. Works Assoc.*, December, 1887.
- , *Consumption by Cities and Towns.* By H. W. Ayres, before the American Water-Works Association. Gives table showing the consumption of water in thirty large cities, extending over a series of years. *Proc. Am. W. W. Assoc.*, Vol. VIII. (1888), pp. 46-49.
- , *Charges for.* Discusses the charges for water by measure and assessment. *Engineering News*, July 23, 1888.
- , *English Towns.* Discusses the bearing of limited water-sheds upon the future supply of English towns, and suggests the prevention of waste of water. Gives experience in the use of waste meters and house-to-house inspection. *Engineer*, June 15 *et seq.*, 1888.
- , *Examination of in Massachusetts.* Abstract of the report of F. P. Stearns,

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- Water Supply.** *Head Required to Produce Velocities in Pipes.* By Chas. B. Brush, before the Annual Convention of the American Society of Civil Engineers for 1888. Gives results obtained in forcing water through a 20-inch main 75,000 feet long. *Eng. and Build. Rec.*, July 14, 1888; abstracted *Eng. News*, July 7, 1888.
- , *Tokio, Japan.* By Yeiji Nakahima. Gives a good history and description of the water supply of Tokio, Japan, with map and illustrations of wood pipes. *Proc. Amer. Water-Works Assoc.*, 1888, pp. 59-55; *Engin. and Build Rec.*, March 17, 1888.
- , A paper by A. H. Denman, attorney, before the American Water-Works Association at Minneapolis, on the legal relations existing between water companies and consumers. A valuable digest of a large number of decisions. *Rep. Proc. 7th An. Meet. Am. Water-Works Assoc.*, pp. 82-92. *San. Engr.*, Dec. 31, 1887.
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- , *Hydrant Service, Rental Value of.* By C. E. Chandler, before the Connecticut Association of Civil Engineers and Surveyors. Discusses the question of the proper price to pay for hydrant service. *Proc. Conn. Assoc. of C. E. & Surv.*, 1888, pp. 10-14.
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- , *Treatment and Sources.* Address of President J. T. Fanning at the eighth annual meeting of the American Water-Works Association. Treats of artificial and natural clarification, deep well supplies, and the protection of sources of supply. *Proc. Amer. Water-Works Assoc.*, 1888, pp. 8-15; *Engr. News*, April 28, 1888; *Engin. and Build. Rec.*, May 5, 1888.
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- , *Safety Valves.* By S. E. Babcock, before the New England Water-Works Association. Discusses the use of relief and safety valves in water-works distribution systems. Abstracted *Eng. and Build. Rec.*, Sept. 1, 1888.
- , *Southwark and Vauxhall.* Full description, with details of pumping engines, etc. *Engineer*, July 3, etc., 1887.
- , *The Tansa, of Bombay.* By K. Hedges. Gives details of the work in progress to give the city of Bombay a supply of 60,000,000 gallons per day. Gives profile of dam to be 8,500 feet long and 118 feet in height. *Engineer*, July 15, 1887. *Engr. and Build. Rec.*, Dec. 31, 1887.
- , *Widnes.* Illustrated description of the new pumps and method of setting, for the Widnes Water-Works. *Engineer*, Aug. 26, 1887.
- , *Ware, Mass.* A well and reservoir system for town of 6,000. A paper by F.

- L. Fuller, giving a full description and cost. *Jour. New Eng. W. Works Assn.*, Sept., 1887.
- Water Supply, Some Practical Details of the Management of.** A valuable paper by Edwin Darling before the M. E. W. W. Association, with discussion. *Jour. New Eng. W. W. Association*, September, 1887.
- , *Use of Vitrified Pipe in.* By S. E. Babcock, before the American Water-Works Association. Gives experience in the use of salt glazed vitrified pipe for conduit. Describes the conduit at Amsterdam and Little Falls, N. Y. Discussion contains description of a conduit of redwood. *Proc. Amer. Water-Works Assoc.*, 1888, pp. 29-46; *Eng. News*, April 28, 1888; *Eng. and Build. Rec.*, May 26, 1888.
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- Water-Works, Boston.** A description, with plan and section, of the Fisher Hill, Boston, reservoir; also plan and sections of the gate chamber. *Eng. News*, March 24, 1888.
- , *Circleville, Ohio.* A brief description of the Circleville, Ohio, water-works, *Rpt. Ohio Soc. Surv. and Engs.*, 1888, pp. 181-183.
- , *Cleveland, O.* By J. Whitelaw, before the American Water-Works Association. Gives a short description and history of the Cleveland water-works. *Proc. Amer. Water-Works Assoc.*, 1888, pp. 114-128; *Engin. and Build. Rec.*, April 28, 1888.
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- , *Denver.* By S. Fortier. Gives a full description of the water-works of Denver, with drawings of many of the details of construction. *Eng. News*, Sept. 22-29, 1888.
- , *Dover, N. H.* Report of Mr. P. M. Blake to the Mayor of Dover on the sources of water supply available for the city. Gives detailed estimate of cost. *Eng. News*, Nov. 26, 1887.
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- , *Liverpool Quarry.* Gives method of quarrying, blasting, flagging and dressing stone, with total cost, for the Liverpool water-works. *Engineering*, March 30, 1888.
- , *Mercer, Pa.* Gives brief description of the water-works at Mercer, Pa., with plans of engine house, well and filter. *Engin. and Build. Rec.*, June 9, 1888.
- , *Minneapolis Pumps.* Gives a brief illustrated description of the pumps in use at the Minneapolis water-works. *Engin. and Build. Rec.*, Sept. 15, 1888.
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- , *Nagpur, India.* Gives a general description of the works for supplying Nagpur, India, with 15 gallons per capita per diem by a gravity system; also contains much information in regard to rainfall, evaporation, discharge and consumption. *Indian Engineering*, March 10 et seq., 1888. Abstracted *Proc. Inst. C. E.*, Vol. XCIII., p. 532.
- , *Racine.* By G. A. Ellis, before the Boston Society of Civil Engineers. Gives a very full description of the water-works at Racine, Wis., and describes method used in the construction of the same. *Jour. Assoc. Engin. Soc.*, April, 1883; *Engin. News*, May 12, 1888.
- Water-Works Statistics,** for many New England cities, for the year 1886, compiled in *Jour. New Eng. Water-Works Assn.*, June, 1887.
- Water Tanks, Iron.** A paper by P. Kieran, and discussion on same. Describes

- 1,160,000 gallon tank at Fall River, Mass. *Jour. New Eng. Water-Works Assoc.*, September, 1887.
- Water Tank, Proper Design for a Hoop Joint of a.** By Prof. J. B. Johnson. Gives the results of tests made on the old forms, and proposes a new design. *R. R. Gaz.* Jan. 6, 1888.
- Water Waste.** A paper by Dexter Brackett. Causes, methods of prevention and results accomplished. *Jour. New Eng. W. Works Assn.*, Dec., 1886.
- Waterways and Railroads.** A paper by U. A. Forbes, before the Society of Arts' Canal Conference. Gives the history of the use and progress of waterways and railroads in England and Wales, and their mutual influence on each other. *Jour. Soc. Arts*, May 25, 1888.
- . See Railroads.
- Waves.** A résumé of our present knowledge of wave motion. *Sci. Am. Supple.*, Nov. 19, 1887.
- Weights and Measures, Report of the Committee of the Boston Society on.** Comprising a canvass of the society regarding metric reform, with opinions of members and a notice of the recent act of Congress. *Jour. Assoc. Engin. Soc.*, July, 1888, Vol. VII., pp. 264-271.
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- Wells, Artesian.** By T. B. Comstock. An abstract of a paper discussing the conditions which must exist for artesian wells. *Rpt. Ill. Soc. Engrs. & Surv.*, 1888, pp. 120-126.
- Wire Gauges.** Chart showing properties of all wire gauges in use. Compiled by S. S. Wheeler. The most complete exposition of the subject yet made. *The Electrical World*, Nov. 12, 1887.
- Woodite.** By Sir Edward Reed. Discusses the use of a new structural material, the base of which is rubber. It appears to be coming into general use in many ways. *Sci. Am. Supple.*, March 31, 1888.
- Wood Pulp Vulcanization.** By M. L. Deering. Describes a new method of treating fibrous material. *Jour. Assoc. Engin. Soc.*, Feb., 1888, pp. 52-55.
- Yacht, Grace Darling.** Gives a brief description, with two page plate, showing longitudinal section, deck plan and cabin plan of the steam yacht "Grace Darling." Length over all, 157 ft.; breadth, 19½ ft.; depth, 11 ft.; draught, 8 ft.; tonnage, 239 tons; engines, quadruple expansion; cylinders, 10 in., 14 in., 20 in. and 28 in. diameter, with 20 in. stroke; 160 rev. per minute; 360 horse-power, with boiler pressure of 180 lbs. *Engineer*, March 16, 1888.
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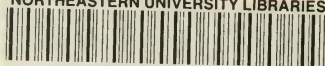
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